EDITION B

The Journal of the INSTITUTION OF PRODUCTION ENGINEERS

Vol. XXI No. 3

MARCH, 1942

CONTENTS

	Page
INSTITUTION NOTES	1a
CAST IRON IN RELATION TO ENGINEERING, by E. J. L. Howard	103
DISCUSSION	117
MECHANICAL PROBLEMS IN THE SETTING OF SPIRIT LEVELS, by Frederick Grover (Member)	123
ABSTRACTS	XXX

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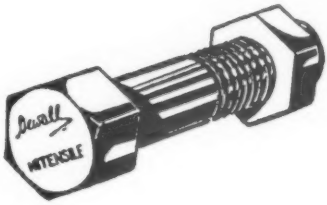

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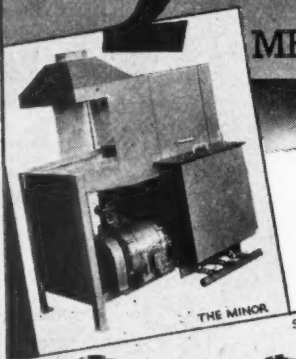
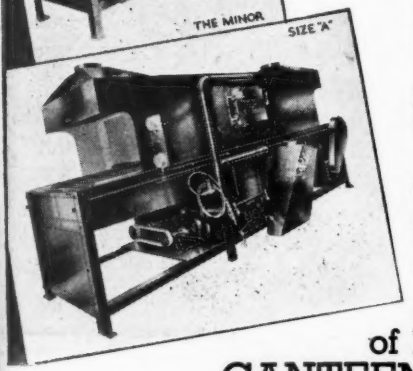


THE MINOR



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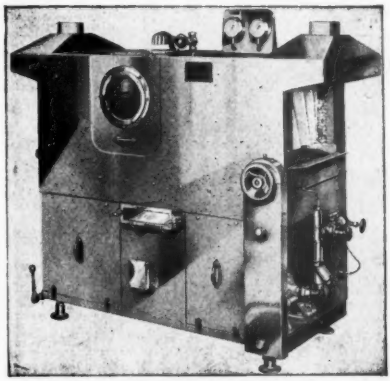

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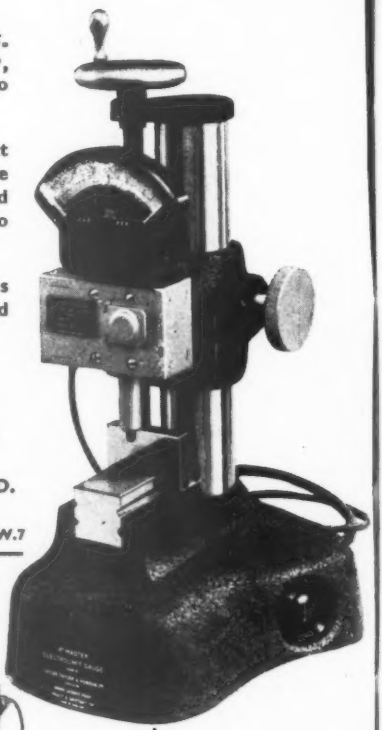

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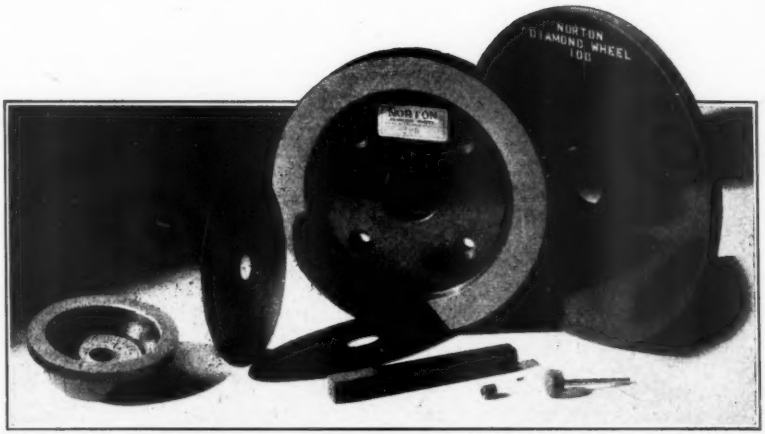

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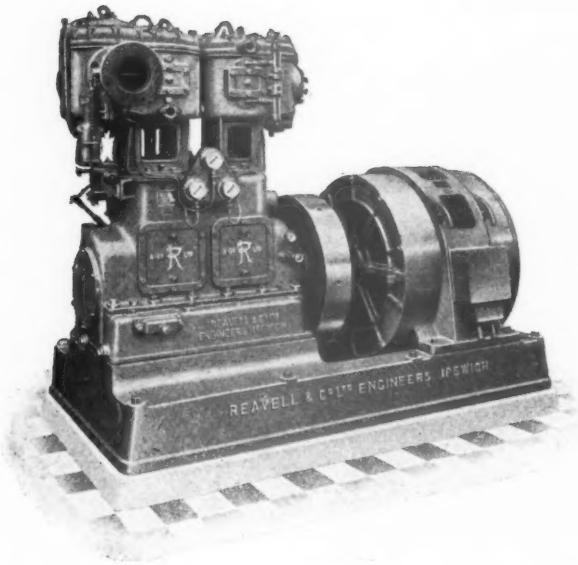

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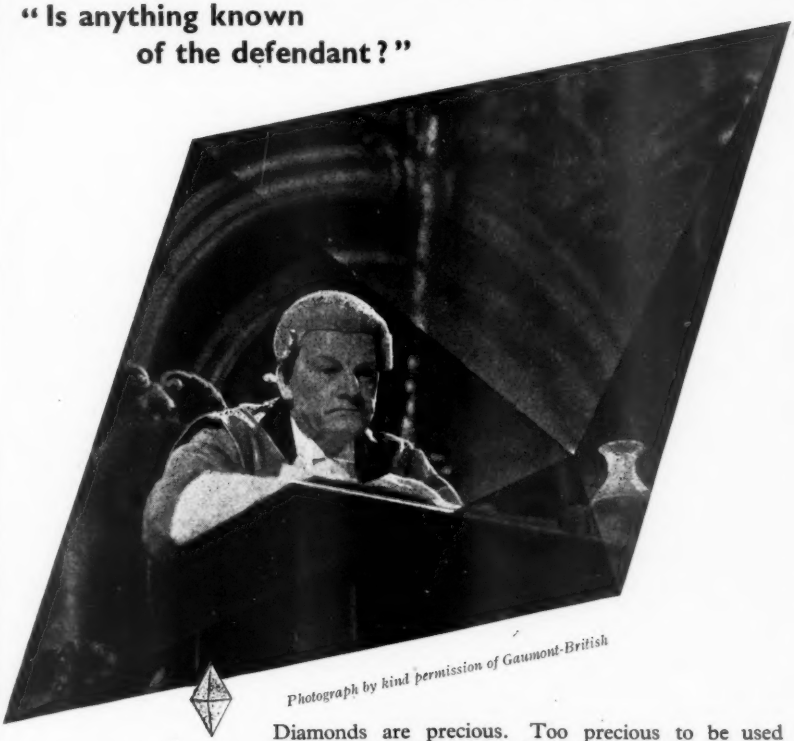

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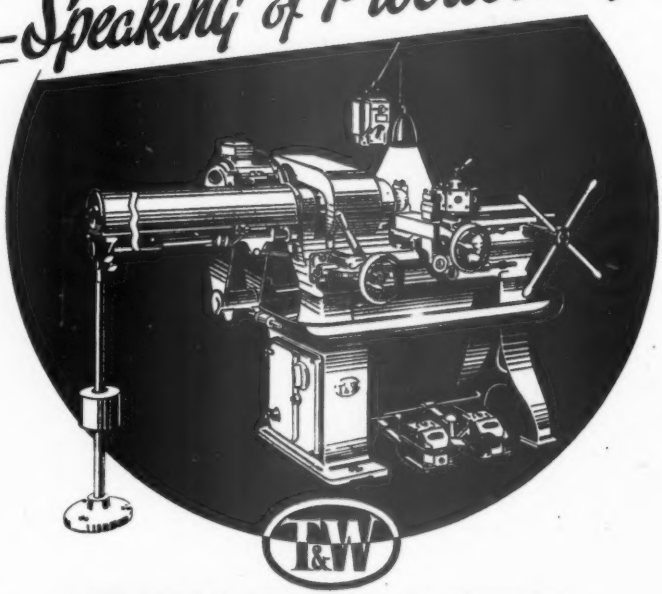

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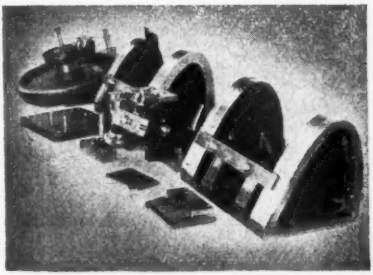

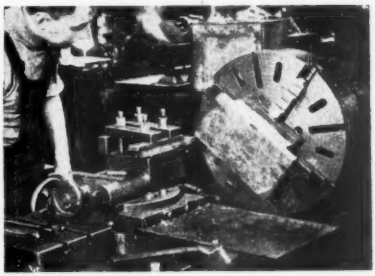

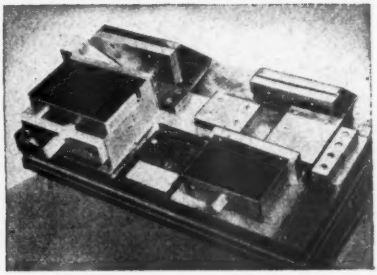

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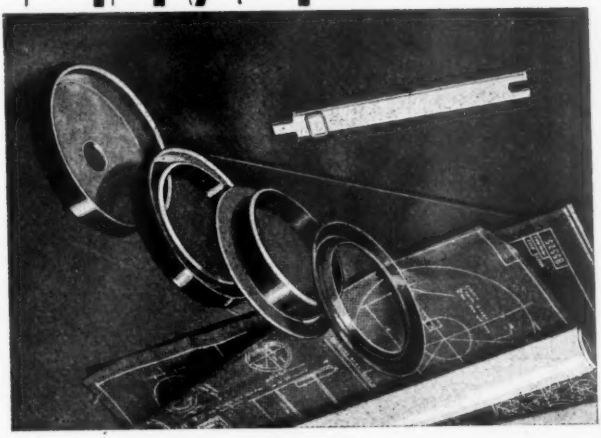

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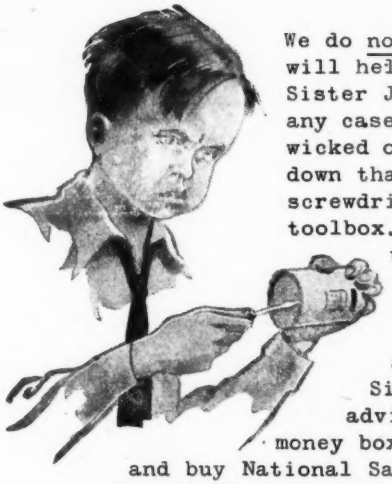
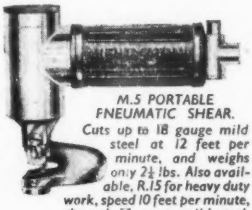


We do not make a tool that will help you to bust open Sister Jane's money box. In any case it would be very wicked of you to try, so put down that poker and the screwdriver from Daddy's toolbox. (What's the matter with a sharp pair of scissors, anyway? Dear, dear, what are we thinking about?) And tell Sister Jane that we advise her to take the money box to the Post Office and buy National Savings Certificates. We do make tools for cutting sheet metal of course. The Desoutter Shear, for instance, will cut through 18-gauge Mild Steel at the rate of 12 ft. per minute. But it was never meant for money boxes. Sorry, Michael.



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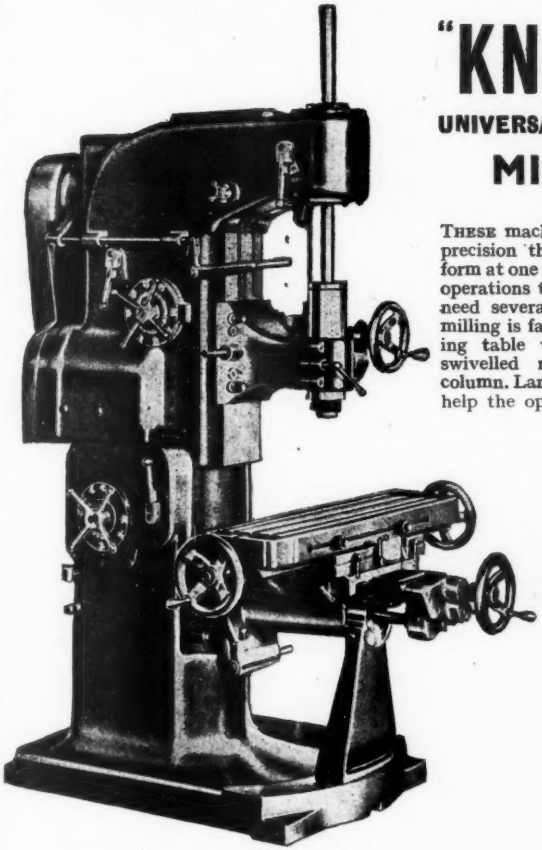

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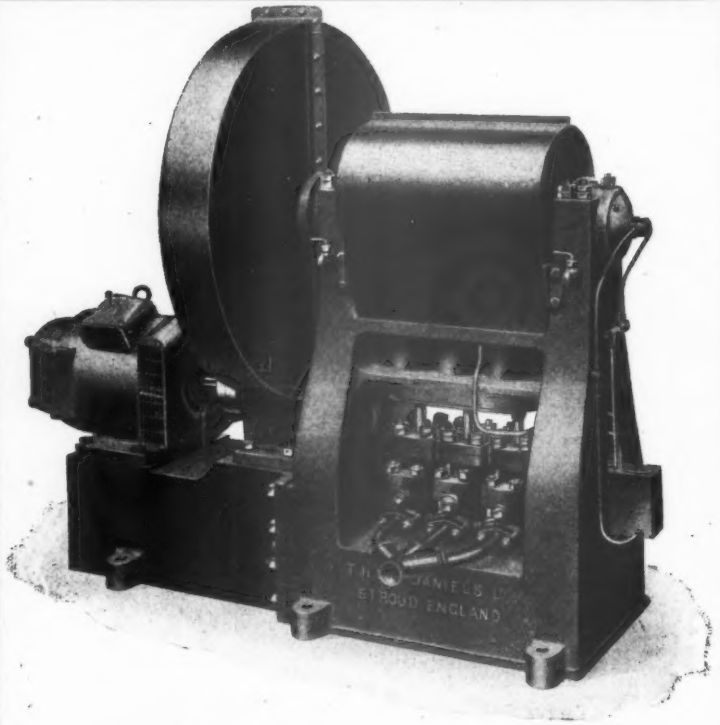

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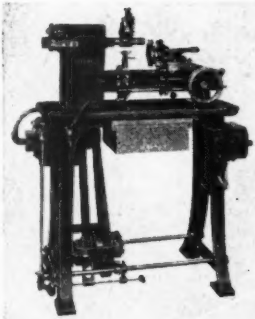

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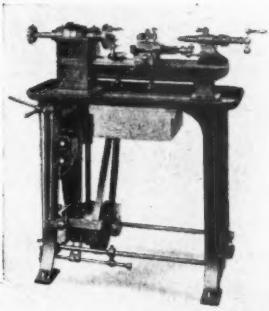
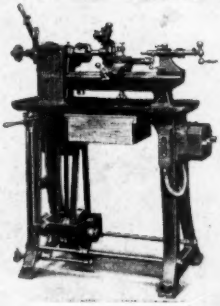
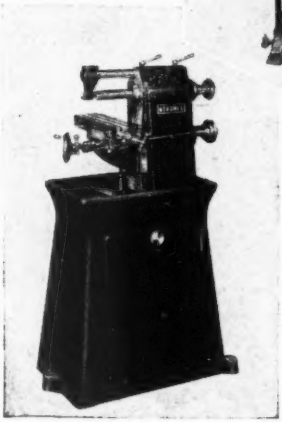


Stedall Instrument Lathes



Stedall Chasing Lathes



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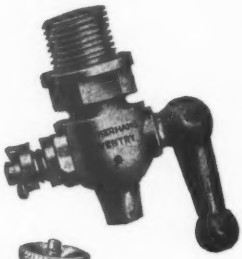

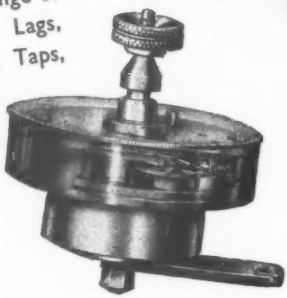

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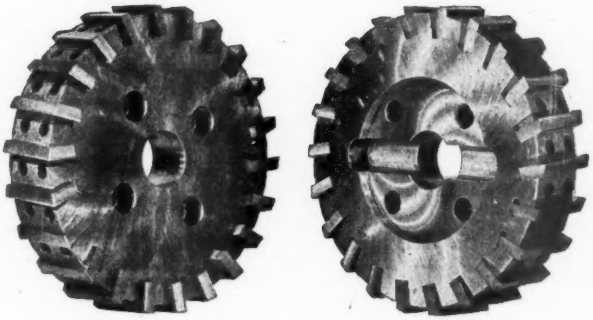
MILLING CUTTER BLADES



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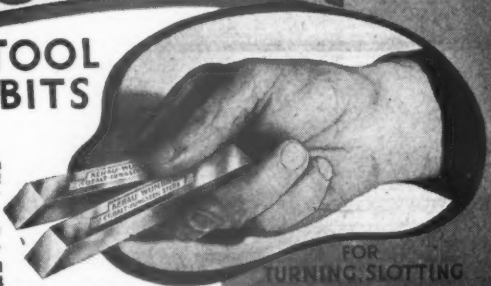

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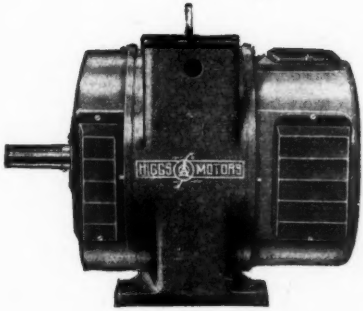

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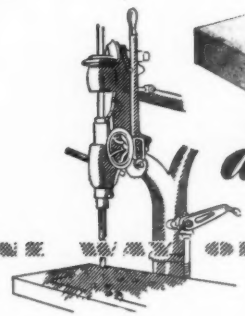

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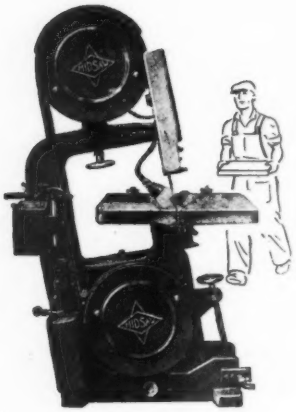

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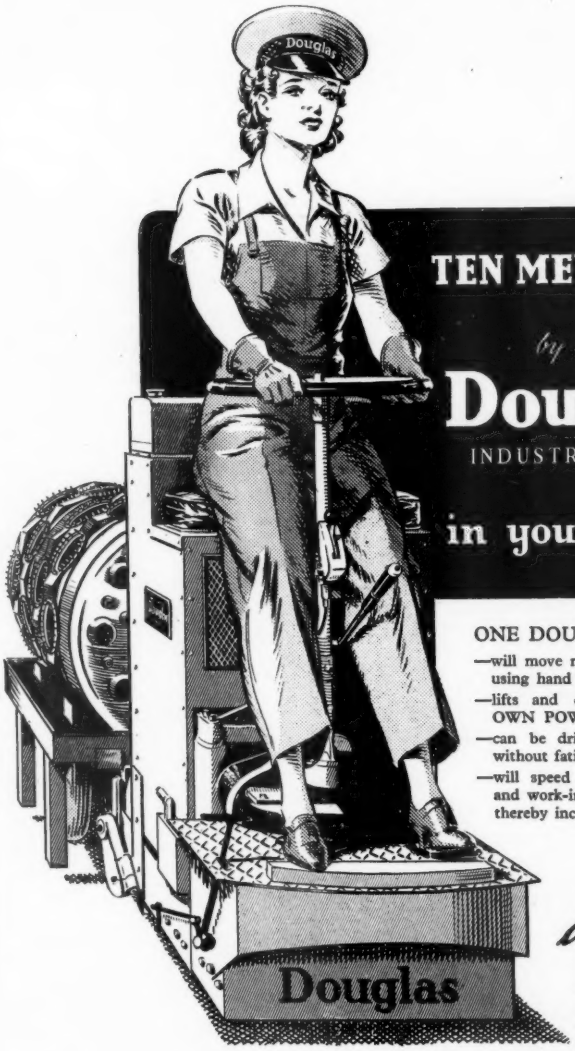

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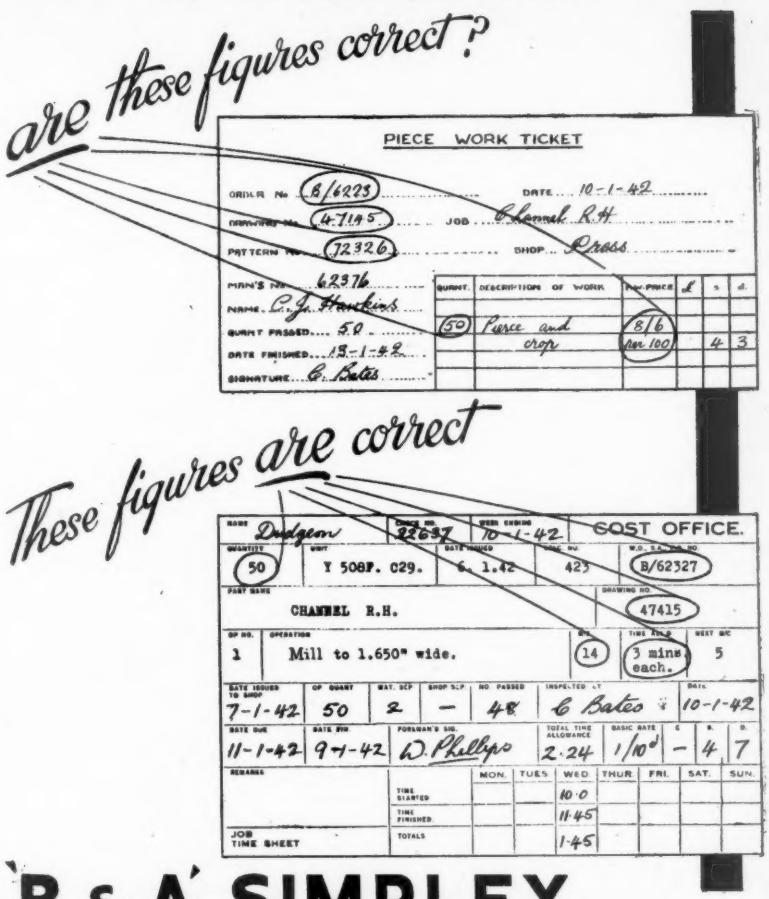
INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A and B. Advertisers' announcements only appear in one edition each month, advertisements in edition A alternating with those in edition B the following month. This Index gives the page number and edition in which the advertisements appear for the current month.

	Page
Arnott & Harrison, Ltd.	vi A
Automatic Coil Winder Co., Ltd.	xvii A
Barber & Colman, Ltd.	x B
B.E.P. Ltd.	xxiv A
Block & Anderson, Ltd.	xxix B
Bratby & Hinchliffe, Ltd.	xxx B
British Aero Components, Ltd.	xxiii B
British N.F.S. Co., Ltd.	xii B
Broadway Engineering Co., Ltd.	xv B
Brown, David, & Sons (Hudd.), Ltd.	xxvii A
Burton, Griffiths & Co., Ltd.	ii A, xxvi A
Catmur Machine Tool Corporation, Ltd.	iii A
Cooke, Troughton & Sims, Ltd.	xiv A
Daniels, T. H. & J., Ltd.	xvi B
Dawson Bros., Ltd.	iii B
Deloro Smelting & Refining Co., Ltd.	xxi B
Desoutter Bros. Ltd.	xiii B
Douglas (Kingswood) Ltd.	xxvii B
Drummond (Sales) Ltd.	xxiii A
Herbert, Alfred, Ltd.	xxv A, xiv B
Higgs Motors, Ltd.	xxv B
High Duty Alloys	xix A
Holman Bros., Ltd.	xxxii A
Hughes, F. A., & Co., Ltd.	xiii A
International Twist Drill	xxxi B
Jackman, Geo., Machine Tool Co., Ltd.	xxii B
Jessop, William & Sons, Ltd.	xx B
Leytonstone Jig & Tool Co., Ltd.	ix B
Macrome Ltd.	xx A
Metropolitan Vickers Electrical Co., Ltd.	xxxii B
Midgley & Sutcliffe	xii A
Midland Saw and Tool Co., Ltd., The	xxvi B
Mollart Engineering Co., Ltd.	viii A
Motor Gear Engineering Co., Ltd.	xxiv B
M.P.J. Gauge and Tool Co., Ltd.	xx A
National Alloys, Ltd.	vii A
Newall, A. P., Ltd.	ii B
Newall Engineering Co., Ltd.	xxx A
Norton Grinding Wheel Co., Ltd.	v B
Optrex, Ltd.	xxii A
Parkinson, J., & Son	iv A
Pryor, Edward, & Son, Ltd.	xxiv A
Rawlplug Co., Ltd., The	xviii A
Reavell & Co., Ltd.	vi B
Rotherham & Sons, Ltd.	xviii B
Sanderson Bros. & Newbould, Ltd.	xxiv B
Schrader's, A., Son	xxi A
Snow & Co., Ltd.	xix B
Stedall Machine Tool Co., Ltd.	xvii B
Taylor, Charles, Ltd.	xxix A
Taylor, Taylor, & Hobson, Ltd.	iv B
Tecnaphot, Ltd.	xxii A
Timbrell & Wright Machine Tool Engineering Co., Ltd.	viii B
Turbine Gears, Ltd.	x A
Urquhart, Lindsay & Robertson, Orchar, Ltd.	xv A
Vaughan, Edgar & Co., Ltd.	xi B
Voucher Ltd.	xxii B
Ward, H. W., & Co., Ltd.	v A
Ward, Thos. W., Ltd.	xi A
Wearden & Guylee, Ltd.	xxxi A
Wickman, A. C., Ltd.	ix A vii B
Zinc Development Association	xvi A



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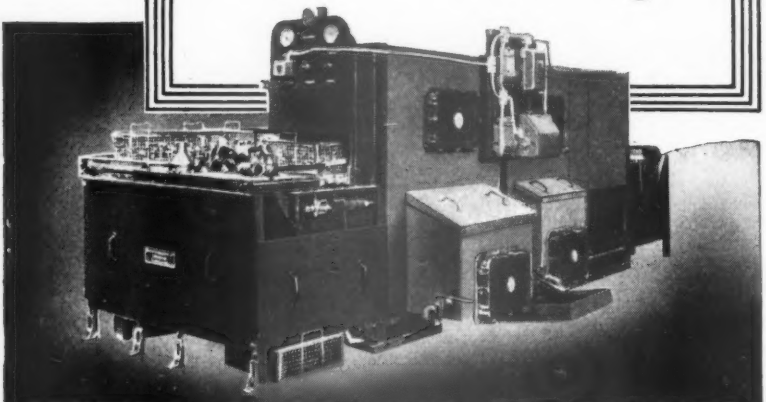

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INSTITUTION NOTES

March, 1942

Fixtures

April 9—Inaugural Meeting of the Northern Ireland Section, Belfast.

April 11—London Graduate Section, 3 p.m., at Institute of Mechanical Engineers. Three short papers on Welding.

April 14—Birmingham Graduate Section. Paper by Mr. C. F. Gazard, Graduate, preceded by annual section meeting.

May 1—London Section. "Surface Finish," by Dr. G. Schlesinger, Director, Research Department, at Institution of Mechanical Engineers, Storey's Gate, 6-30 p.m.

Subscriptions Received for Research

Since the list in last month's "Notes" the following subscriptions for the work of the Research Department have been received:—

	£	s.	d.
Westland Aircraft Ltd.	10	10	0
Birmid Industries Ltd.	25	0	0
	£35	10	0

Production Control Committee

Mr. T. W. Price has been appointed Chairman of the Production Control Sub-Committee which is now meeting in London every week. Other members are Messrs. W. Adams, R. Appleby, B. G. W. Attwood, W. R. Childs, J. Cooper, and H. Whittaker. The question of setting up sub-committees in other centres is under consideration.

Deputation to the D.S.I.R.

The President, Mr. G. E. Bailey, introduced a deputation from the Institution to the Department of Scientific and Industrial Research on February 27th in connection with the work of our Research Department.

New Memorandum on Production

At its meeting this month the Council of the Institution considered the terms of an important memorandum on the present production position prepared by the War Emergency Committee. The memorandum was at once submitted to the new Minister of Production, Mr. Oliver Lyttelton, and will appear later in *The Journal*.

Paper Shortage: Journal Advertisements

It is regretted that owing to the paper shortage it has become necessary to curtail the space devoted to advertisements in *The Journal*. The plan decided on is to divide the advertisements each month into two sections, and to arrange that members and others who receive *The Journal* will get copies of each section in alternate months.

Research Department Reports

Great interest is being shown by members and others in the two latest reports of the Research Department of the Institution, one on "Surface Finish" and the other on "Acceptance Test Charts for Machine Tools, Part II." There has been a brisk demand for both of these reports.

Meeting of the Council

The Council met at Leicester on March 20th, Mr. N. V. Kipping, Chairman, presiding. Other members present were Messrs. J. H. Bingham, J. E. Blackshaw, D. Burgess, J. W. Davies, W. F. Dormer, E. P. Edwards, J. France, T. Fraser, H. J. Gibbons, J. R. Gimson, G. H. Hales, J. A. Hannay, H. A. Hartley, J. T. Kenworthy, C. W. Mustill, J. D. Scaife, M. H. Taylor, and I. H. Wright. Also present: Messrs. L. Austin, L. E. Broome, H. S. Burdett, N. A. Cullin, E. W. Harbot, L. H. Leedham, V. D. Pavord, J. Pollard, A. J. Pratt, R. C. Shuster, J. Wombwell (Leicester Section Committee), L. Shenton (hon. secretary, Nottingham Section), and R. Hazleton (General Secretary).

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "The Journal" should not be taken as an indication that they are necessarily available for export.

CAST IRON IN RELATION TO ENGINEERING

Paper presented to the Institution (Preston Section), by E. J. L. Howard.

MODERN engineering construction demands cast iron possessing properties unheard of a few years ago, and constant research on the part of engineers, metallurgists, and foundrymen has resulted in the development and production of cast iron of higher strength, increased resistance to wear and abrasion, corrosion, and temperature. As these developments have taken place, so have the foundries in which the castings are produced improved in methods of production and lay-out. Most modern foundries are now, to some extent, mechanised, some wholly, others only where experience has shown it necessary to cope with the developments which have taken place. There has possibly been a tendency to over-mechanise in some cases, particularly where the foundry deals with a multiplicity of castings.

Probably one of the greatest advances made has been the production of high-strength cast iron. Twenty years ago cast iron was generally considered a material with a tensile strength of about 12 tons per square inch, but nowadays castings are produced with tensile strengths approaching 30 tons per square inch. The progress made in research and development can well be judged with reference to specifications which so rapidly reflect research progress. In 1928 the first general specification for grey iron castings, No. 321, was issued by the British Standards Institution. It had three test pieces of two grades of iron at 10 and 12 tons per square inch tensile strength. In 1938 the specification was issued in revised form with five test pieces, and was accompanied by another specification for high duty irons (No. 786), giving three categories of grey cast iron of better quality than those in 321, and going up to a figure of 22 tons per square inch. It is evident that in making it possible for any buyer of castings to demand such improvements in quality, considerable developments have gone on throughout the industry.

The common phosphoric irons—that is, those containing generally over 1% of phosphorus—will fail to meet the specification for grade "C" of B.S.S. 321, which calls for a tensile

March 20th, 1940. (Vol. XXI, No. 3, March, 1942).

of 10 tons per square inch and a transverse of 960lbs. on the 0.875in. bar. To meet the grade "A" specification, which calls for 12 tons per square inch and a transverse figure of 1,185lbs., the phosphorus content must be reduced to 0.8%, although if the iron is carefully melted, and the carbon and silicon contents used to ensure the phosphorus to be in network formation, the required figures can be met.

If the common irons be taken as below that of grade "C," 10 tons per square inch, and ordinary iron between 10 and 12 tons per square inch, these two grades cover ordinary engineering castings. Special irons have higher strengths. For many years iron usually described as cylinder iron has had a tensile strength of about 15 tons per square inch, while the higher grade work for Diesel engine service possesses a strength of about 18 tons per square inch. This may be taken as a point of departure for modern high duty irons, which may roughly be defined as irons having a tensile strength of over 18 tons per square inch, the strength being the maximum which can be ordinarily produced in the foundry by exercising the greatest possible care, using the best technique but without employing special processes or alloy additions.

High-strength cast iron can be divided into two classes: first, those known as alloy cast irons, where special alloys are added to the metal, and, secondly, where a high strength is obtained mainly by careful control of carbon and silicon contents of the iron. Both of these types are relatively low carbon iron, and may be improved still further by a suitable heat treatment. The well-known inoculated irons produced by melting metal which would normally solidify white, but which, after heat treatment in the molten condition by a graphitiser, yield close grain grey iron with excellent physical properties, are an example of obtaining high strength grey irons without the use of alloy additions. Such irons can, of course, be further improved by the use of small amounts of certain alloys. In producing these irons a powdered graphitiser is usually added to the metal as it is tapped into the ladle, but a similar effect is produced where the white graphite-free melted metal is inoculated or greyed by small additions of molten grey iron. This process requires two furnaces, and is known as the two-cupola process. Steel is melted in one furnace with additions of ferro silicon and ferro manganese. In the other furnace ordinary iron is melted, and a predetermined amount of this iron is poured into the ladle containing the hard iron. The resultant metal produces castings which are finer grained and of higher tensile strengths than those made from similar analysis when melted in the ordinary manner in one cupola. Metal made

in this manner does not "draw" very much, and internal shrinkage is less. It is very suitable for castings which necessitate the resistance to high pressures, such as boilers and valves.

The ordinary elements of composition in cast iron are carbon, silicon, manganese, sulphur, and phosphorus.

Phosphorus affects the mechanical properties of cast iron to a great extent. It exists in the metal in the form of phosphide eutectic, a hard brittle material which penetrates the main structure of the metal somewhat like a wire mesh. If the lines of network are continuous throughout the metal, the metal is brittle. This has been responsible for the tendency in recent years to lower the phosphorus content of high duty irons to a point on which the network is broken and discontinuous in order that the mechanical properties may be governed by the matrix. However, irons showing a pronounced network can be made strong, and are indeed stronger than badly melted and poor quality irons of the same phosphorus content in which the phosphorus segregates unevenly. To ensure a satisfactory network the carbon and silicon contents should be kept low. The general tendency, however, is to reduce the phosphorus content to a point at which the continuous phosphide network no longer exists.

In the production of strong irons there is little necessity to modify the manganese and sulphur contents, but the manganese should be present in such proportions as will completely neutralise the sulphur and compel the formation of manganese sulphide. The proportion needed of manganese is 1.7 times the sulphur plus 0.3% in the casting, to which an addition of, say, 0.2% manganese must be made for manganese loss and sulphur increase in melting.

Carbon and Silicon

The chilling properties of an iron or the extent to which it forms close grain or open grain material are governed by the carbon and silicon contents. In a series of irons of the same section, the same silicon content the higher the carbon the closer the graphite and hence the more open the grain the weaker the iron will be. Similarly, for a series of irons of the same section and the same carbon content, the higher the silicon content the closer the graphite and the more open the grain and weaker the iron will be. If the carbon and silicon contents are increased together the metal rapidly becomes more open, and vice versa. Much of the improvement in modern cast iron is due to the use of irons in low silicon, whereby it becomes possible to work closer to the margin of unmachinability. It is also possible to increase

the strength by lowering the carbon content, which not only reduces the amount of graphite present in the structure, but reduces the size of the individual flakes.

Alloy Additions

In addition to reducing the amount of brittle phosphide eutectic by cutting down the phosphorus and by producing pearlitic irons, much has been done towards strengthening cast iron by suitable alloy additions. In these additions, nickel, copper, chromium, and molybdenum are most important, and if used in the correct manner, with due regard to the composition to which they are added and the service for which the casting is required, they are valuable additions, the benefits which they confer in service outweighing the cost of additions.

Nickel

This is probably the most widely used of all the alloying elements in cast iron. An addition of 1% to 2%, especially in replacing part of the silicon content in intricate castings where the section varies widely in different parts, is a valuable aid to producing homogeneous metal. The element acts as a softener in thin sections, but yields a hard dense metal in thick sections. High strength and machinability, as well as hardness and wear resistance, may be obtained by the addition of 1¼% nickel. Machine tools are an example of this. The addition of 3% to 6% nickel yields irons which are valuable for resisting abrasion and wear, the lower nickel content being particularly suitable for heat treatment. The addition of 12% to 20% nickel results in the production of austenitic irons of the Ni-resist and Nicrosilal types.

Chromium

Small additions of chromium, 0.5% to 1%, improve heat resistance under certain conditions. In conjunction with nickel, it is added for the production of high strength irons which are suitable for heat treatment. The addition of between 20% and 35% chromium yields irons which are particularly good for resisting corrosion of certain types.

Molybdenum

The influence of this element is rather complex, and depends partly on the composition of the base irons. Small additions of 0.3% to 0.7% have proved very effective for improving strength, and this element has been found especially valuable in cases where resistance to fatigue and shock are required. Many applications have been found in the automobile industry, and

molybdenum cast iron is now being used for brake drums, crank and cam shafts, gears, valve seats, etc. It is also being used for the addition to cast iron for the roll industry.

Copper

A well-known application of copper as an addition to cast iron is in the nickel austenitic irons of the Ni-resist type. Small additions of this element, 1½% to 2½%, have been used in some of the newly developed cast crankshafts, where it is said to increase the fluidity of the molten metal and to improve its resistance to impact. It has also been stated that copper in small amounts reduces the atmospheric corrosion of grey iron.

One of the earliest methods of producing a strong iron in a low silicon mixture was to pour the molten metal into moulds preheated to such a temperature that the metal cools in a grey pearlitic condition. The process was patented in Germany, and known as the Lanz or Pearlit iron. The process is limited to size of mould that can be treated. The composition of the metal, thickness of casting, and temperature of the mould are correlated, and grey machinable castings can be produced containing silicon as low as 0.5%. The manufacture gives a large grain size, and, on account of slow cooling, large graphite flakes. Sounder castings are produced, due to retarded cooling, gradual freezing, better feeding, and freer egress of gases. Internal stresses are also probably reduced, due to the slow cooling. An iron containing 0.68% of silicon will give a tensile stress of 17 tons per square inch, and a Brinell hardness of 220.

Emmel Iron

This iron is made from a high proportion of steel scrap, and has a low carbon content. It was originally patented in Germany. Due to the large amount of steel scrap, the iron has a high shrinkage, but this may be offset by a high silicon content. An iron having a total carbon of 2.5%, silicon 2.6%, and phosphorus below 0.1%, will give a tensile stress of 20 tons per square inch.

Inoculated Irons

Experience has shown that superheating of cast iron refines the graphite, and if the superheating is sufficiently high and the time sufficiently long the iron ultimately solidifies white. Cast iron melted under ordinary conditions does not dissolve away all the graphite, due to time of melting and the temperature being inadequate. Superheating, on the other hand, gives the graphite particles an opportunity to completely dissolve; and unless some particles exist in the melt, on which graphite could build up

during cooling, there is a tendency for the metal to solidify in the white state. By the addition of graphitisers to the molten iron it is possible to restore it to the grey state. These graphitisers have been called inoculants. The object of inoculation is to create artificial graphite centres on which small flakes can be formed, and which will yield a grey and machinable but strong iron. It is possible to take a common iron, which would normally show a coarse structure after remelting, and to refine the graphite by superheating or by steel additions, and subsequently, by inoculation or the artificial replacement of graphite flakes, to make it solidify finally with fine flake graphite. It is quite practicable to produce iron of high tensile strengths of the order of 25 and even 30 tons per square inch by this method.

Meehanite

This is the name given to an iron originally produced in the United States. It is a low carbon and low silicon iron composed largely of steel scrap, and is melted and made grey at the cupola spout by an addition of calcium silicide which is added to the metal stream by means of a small hopper, controlled by a small electric motor and adjusted to deliver the silicide at a pre-determined rate. This grade of Meehanite is stated to give a tensile of 20 to 23 tons per square inch with a Brinell of 200, and if the metal is deliberately cast in the white state and annealed, higher figures can be obtained. It has been stated that Meehanite "A" in the as-cast condition will give a tensile strength of 24 tons per square inch and a Brinell figure of 270. After heat treatment the tensile strength has risen to 50 tons per square inch, the Brinell figure remaining the same, 270. A charge might be composed of 60% steel scrap, the remainder being cast iron, scrap, and ferro silicon to give a silicon content of 1.2%, and calcium silicide added to the molten metal as previously described. Such a charge would give a tensile strength between 21 and 23 tons per square inch, with a Brinell hardness of about 240.

Ni-Tensile

This is another type of inoculated high strength iron covered by a British patent 290265/27. The U.S. patent is held by the International Nickel Co., and the British patent by the Mond Nickel Co. The inoculation treatment which is carried out when the metal is molten and shortly before the castings are poured consists in adding sufficient nickel and silicon to give effective graphitisation, the amount depending upon the size of casting being made. Satisfactory results are assured in most cases by keeping the silicon content between 1.25% and 1.75%, and by adding 1% or 2% of nickel. The alloy produced by this process

usually has a tensile strength of 25 tons per square inch, and is relatively hard, due to the fine and dense structure resulting from the low carbon content and inoculation treatment. Hardness values as high as 280 Brinell have frequently been obtained, yet the metal has proved easier to machine than ordinary cast iron. It is amenable to heat treatment, and by applying a simple quench and tempering operation strength figures of 30 tons per square inch and over have been obtained repeatedly in common castings. In addition to high tensile strength, the alloy shows remarkable resistance to impact.

These high duty irons, Meehanite and Ni-Tensile, are of importance to engineers to-day, offering, as they do, an advance of approximately 50% over the strength of ordinary iron castings. This opens up the possibility of reducing the section thickness in large castings, as, for example, in winding drums and other parts, where, by reducing section and weight, substantial savings in power are possible. On the other hand, these irons may be used without alteration in design to enable higher stresses to be adopted, whilst perhaps of more interest still is the fact that with the higher strengths these irons may be adopted in place of steel castings. This is of special interest at the present time when the difficulties of obtaining steel castings are well known.

Examples of the application of these irons include large winding drums, machinery castings, parts for electric motors, bodies for pumps, machine tool parts, clutches and gears, and, in fact, all parts where something better than ordinary cast iron is required.

An important high strength application is in dies for pressing or blanking sheet steel. It has been found that an iron containing about 1.5% nickel and 1.5% silicon, with a carbon content of about 2.8%, is particularly suitable in the as-cast condition for large and complicated dies, as well as for small dies used for drop forgings. In this condition a hardness of 230 and a tensile strength of 25 tons per square inch are obtained. For smaller dies the same iron in the oil hardened condition may be used, the iron being oil quenched from 850° C., and tempered at 350° C., resulting in a tensile strength of 30 tons per square inch and a Brinell hardness of 400. The use of this iron for dies has economic advantages, because instead of using complete design involving many parts in different metals, in many cases it is possible to cast the whole die in one piece, in such a way that after machining and with or without heat treatment the desired properties of strength and wear resistance can be obtained.

Heat Treatment

The improvement in physical properties of iron castings by heat treatment is vitally important in the production of high duty

cast iron. Generally speaking, in most types of castings, particularly of complicated design, beneficial results are obtained by annealing at a temperature of 400° C. for a shorter or longer time, depending on the thickness. Such annealing, besides releasing stresses, even increases the tensile strength 20%, or even 30%, without impairing its hardness or wearing qualities. The treatment releases strains which might subsequently cause cracking in service, and is further of advantage in eliminating any need to age or weather the castings to prevent distortion after machining.

Quenching and tempering are now being applied regularly to alloy castings of relatively heavy section. Until recently heat treatment as applied to steel castings could not be used in connection with cast iron, due to the danger of cracking owing to quenching stresses. The advantage of nickel has made heat treatment possible owing to its influence in reducing the critical speed and cooling necessary to produce a given result. Thus, whereas in the case of plain cast iron it would often be necessary to give a water quench in order to obtain response, in the case of an iron containing 2% nickel quenching in oil is nearly always sufficient, the latter treatment being, of course, much safer for castings. It is well known that by quenching an iron containing about 2% nickel in oil at 850° C., followed by tempering between 300 and 450° C., a marked improvement can be obtained in the hardness and tensile strength and wearing qualities of the iron. This treatment is being regularly applied to such castings as gears, cylinder liners, cams, and other machinery parts. By heat treatment it is possible to obtain strengths of over 35 tons per square inch, together with Brinell hardness values of 200 to 400. An interesting example of heat treatment of cast iron has been found in connection with automobile crankshafts. Experiments have revealed that cast iron possesses a valuable property, and that it tends to damp out vibrations to a far greater degree than does steel. At the same time it has been found that cast iron possesses a useful degree of fatigue resistance, and these factors, coupled with heat treatment of modern high strength irons, have resulted in the adoption of cast iron crankshafts on an extensive scale in the United States, whilst they have also received a considerable amount of attention in this country.

Corrosion-resisting Cast Irons

At the present time there are three main types of corrosion-resisting cast irons available for the engineer. The first to be developed of this type was the high silicon cast iron normally containing about 15% of silicon. These are known by a variety

of names, such as Ironac, Tantiron, and Anti-acid. As far back as 1903 these irons were used for handling various types of acids, but the iron suffers from several serious production disadvantages, inasmuch as it is unmachinable and extremely brittle.

In the early days when ferro-silicon was first introduced, attempts were made to analyse it by the usual methods, but it was found that it was more or less insoluble in acids, except hydrofluoric. From this it was only natural that in due course a modification of this should be put forward for the construction of acid-handling equipment. Due to manufacturing difficulties, the early use of high silicon cast iron was confined to small castings, and large-scale acid-handling equipment did not become available in this country and in the United States until about 1912. During the last war the material was developed extensively in the construction of plant for the production of explosives and succeeded earthenware and pottery, as formerly used, for the condensation of nitric acid, in view of the speed with which it could be manufactured and the increased efficiency brought about by its use. For example, due to its greater heat conductivity, a condenser built of high silicon cast iron handled a charge of nitric acid in 16 hours against 36 hours when pottery was employed as the material of construction.

As the amount of silicon is increased in cast iron, the physical and chemical properties vary considerably. Satisfactory resistance to acid attack is not obtained until the silicon content approaches 13%, and at 19% and upwards the corrosion-resisting properties again fail. The maximum resistance against sulphuric, nitric, and hydrochloric acids at 10% concentration is as follows:

10% Sulphuric acid	14.8% to 17.3% silicon
10% Nitric acid	16% silicon
10% Hydrochloric acid	18% silicon

In practice, the composition employed should come within the following limits:—

Silicon	13.0% to 18.0%
Carbon	0.2% to 1.0%
Phosphorus	0.2%
Manganese	0.2% to 2.0%
Sulphur	0.05% maximum

In view of the hardness of the high silicon irons, machining cannot be conducted, and castings must be finished by grinding. As a general rule, any material in this class which can be machined with a cutting tool is unsatisfactory for severe corrosive work. The high shrinkage of these alloys is also a troublesome factor

in the foundry, and recent investigations disclose that this property is partly related to the state of the carbon. Additions of other metals are not usually made to high silicon irons, but it has been found that an addition of about 2% nickel increases the resistance to corrosion slightly.

All castings to be made in this type of iron must be designed from the very beginning with careful regard to the properties of the material. Sharp angles should be avoided, and sudden changes in sections replaced by generous fillets. Vessels such as boiling pans, receivers, stills, etc., should be made with a curved bottom, as large flat surfaces present contraction difficulties. All joints in pipe work must be formed by means of flanges or spigot and socket, since the metal is too hard to screw or thread. Welding operations can be conducted on this material, but success is difficult to obtain, in view of cracking difficulties caused by the inherent properties of the alloy, although the Duriron Co., in America, have developed a successful technique in this direction.

Properly made high silicon cast iron castings have an excellent resistance to attack by both hot and cold sulphuric and nitric acids, either as single or mixed solutions. They are not considered suitable for handling hot concentrated sulphuric acid, although the resistance to weak hot solutions and cold concentrated solutions is fairly satisfactory. Failure has at times been experienced in handling fuming sulphuric acid, as silicon is readily exposed by sulphur trioxide.

As well as being acid-resisting, these irons can be used against other corroding media. They have also been utilised for erosion as well as corrosion-resisting purposes, such as pipes for handling wet sand. The chief products made of high silicon iron are acid pans, caseade basins, stills, retorts, autoclaves, separator and condenser parts, de-nitrating towers, pumps, stop cocks, pipes, and fittings, etc. The material cannot be recommended for vessels which have to be worked at an internal pressure higher than 50lbs. per square inch, and it is also unsatisfactory for standing up to rapid fluctuations in temperature. The danger of cracking may be minimised by providing suitable facilities for expansion, but for pumps and valve, high silicon iron should not be used if the temperature exceeds 40° C. In the case of large tower sections subject to appreciable temperature change, the height must not exceed more than one and a half times the diameter.

Austenitic Cast Irons

About 1927 the high nickel austenitic type of corrosion-resisting cast iron was produced. This is known by a variety of names,

No. 7 Alloy, Nimol, Ni-Resist, No. 33 Alloy, Audcolloy, and Causul. All these alloys have much superior physical properties over the high silicon irons, and are readily machinable, with the result that their development has been rapid, and they are increasingly adopted for service in many branches of industry. All types of austenitic cast iron are not necessarily corrosion-resisting, and, accordingly, my remarks relative to this section will deal essentially with those compositions known to have marked resistance to corrosive attack, such as, for example, irons containing over 13% nickel, together with an appreciable amount of copper and chromium, in addition to the other elements normal to grey iron. Unlike the high silicon iron, the austenitic cast iron is readily machinable. It is not unduly difficult to handle in the foundry, and possesses a range of useful mechanical properties which permit it to be used in a wide range of engineering applications.

COMPOSITION OF AUSTENITIC CAST IRON

Total Carbon	2.5% to 3.0%
Silicon	1.4% to 1.8%
Manganese	0.8% to 1.5%
Sulphur	0.10%
Phosphorus	0.40%
Nickel	13.0% to 15.0%
Chromium	2.0% to 5.0%
Copper	5.0% to 7.0%

PHYSICAL PROPERTIES OF AUSTENITIC CAST IRON

Density	7.5 to 7.6
Tensile Strength, tons/sq. in.	13.0 to 17.0
Brinell Hardness	160 to 240
Contraction (inches per foot)	5/32″ to 3/16″

The recommended composition given applies to castings up to 1in. in thickness. Where heavier sections are encountered it is advisable to increase the nickel content a further 2% or 3%, in order to ensure free machinability. In certain cases, where the presence of copper may prove to be detrimental, such as, for example, in food-handling equipment, or for resistance against alkalies, this element may be omitted, in which case the nickel content must be increased by an equivalent amount. Chromium is included in order to increase the strength and hardness. If the chromium content is excessive, machining difficulties may be

experienced. In certain cases, compositions with nickel increased up to 40% and with chromium up to 15% have been used to meet specially severe conditions.

It will be observed the strength of this material is much higher than the silicon iron previously discussed, and a certain measure of ductility is available which imparts toughness and shock-resisting properties. All the normal austenitic irons are non-magnetic, and this property affords a simple test for readily distinguishing it from ordinary and other corrosion-resisting irons. If the range of properties is to be maintained it is essential that the composition should be fairly strictly adhered to. With castings having varying sections, for instance, from ¼in. up to 2in., it may be found that there is a slight chilling on the thinner sections, causing difficulty in machining, and it is advisable to heat-treat the casting by normalising it at a temperature of 1,000° C. As stated before, a fully austenitic cast iron is generally soft and easily machined. Its susceptibility to surface hardening by cold working, however, necessitates lower machining speeds than for ordinary cast iron, and tools should be kept sharp and in good condition. The best results are obtained by using deep, heavy cuts rather than light feeding at high speeds. These irons can be readily welded by the Arc or acetylene processes, using welding rods of similar material or, alternatively, Monel metal.

The austenitic irons under consideration have a very good resistance to attack by many corrosive agents, and this factor, coupled with adequate machinability, has led to their extended adoption in the chemical and allied industries for valves, pipes, pumps, and various machine parts. They have also proved successful for service in the pottery, textile, and food industries, as well as for general engineering requirements in the handling of acid and industrial waters. The latest development is the use of austenitic cast iron for the production of automobile cylinder linings, as it has been proved under certain conditions of engine operation corrosion plays an important part in cylinder wear. Attention should also be drawn to the fact that due to its work-hardening properties, these materials are of service in those applications where abrasive is present as well as corrosive influences, such as, for example, in equipment handling liquids containing suspended solids, etc.

Many engineering structures in ordinary iron or steel are rapidly deteriorated even when operating under mild corrosive agents, such as river or sea water. Accelerated attack can be brought about by several causes. For instance, electrolytic action, due to contact with a dissimilar metal, such as bronze, or from turbulence and variations in the oxygen content of the liquid itself.

The use of austenitic cast iron is of considerable usefulness in overcoming troubles of this nature, and it might also be noted that this material does not appear to be subject to the defect of graphitic softening not infrequently associated with ordinary iron castings.

High Chromium Cast Iron

A third, and more recent, advance is the advent of the high chromium iron, containing from 20% to 35% chromium.

Composition of Chrome Cast Iron

Total Carbon	1.0% to 2.0%
Silicon	0.6% to 1.2%
Manganese	0.8% to 1.2%
Sulphur	0.05%
Phosphorus	0.10%
Chromium	24.00% to 32.00%

Physical Properties of Chrome Cast Iron

Density	7.40 to 7.45
Tensile Strength, tons/sq. in	30.00 to 37.00
Brinell Hardness	200 to 300
Contraction (inches per foot)	0.25

It has been found that if a reasonable measure of machinability is to be obtained in the cast state with this material it is important to limit the carbon content between 1% and 2%. Above 2% of carbon an exceedingly hard and stable carbide is formed, which is not readily broken down by heat treatment. Accordingly, the main point of primary importance in the founding of high chromium cast iron is to ensure accurate control of the carbon content between the limits stated. This is not a very easy matter, as it entails the use of ferro-chrome containing low carbon content, which is costly.

These irons have a particularly good resistance to the corrosive effect of many industrial waters, and under such conditions are more or less rustless. Plug cocks and valve faces made from the alloy and various wearing parts of pumps have given excellent service. The material does not score or seize readily, and wears well, due to the presence of a small amount of graphite. It resists abrasion under corrosive conditions and compressive stresses to a high degree. Cast irons of this type have an excellent

resistance to the attack of nitric acid, but fail in the presence of sulphuric and hydrochloric acids. From corrosion tests conducted it would appear that their use might also be considered for service with sulphurous, acetic, citric, and carbolic acids, as well as for several other chemical solutions. It should be clearly understood that one must never expect to find a single alloy which is universally resistant to every service condition. All of the corrosion-resisting cast irons discussed have their individual advantage for some special application.

Discussion

MR. BAILEY: To-night we have heard a very interesting lecture from Mr. Howard. In some respects it was a little bit technical, so I would like to ask Mr. Howard if he would make just a little more clear what he means by heat-treatment of the Ni-tensyl type of material. What chemical or other action takes place to give you that close grain? He mentioned the question of using the high duty iron for dies. I would particularly like to know whether it is suggested that those dies should be used for blanking, or merely the foundation of dies for blanking, where special blanking steel is used just for the cutting edges. As to weldability and the various types of iron mentioned, I think I am right in saying the austenitic was good for weldability, but is there any information that can be given concerning the Ni-tensyl type of iron where welding might have to take place? Would it be by heating the iron and then welding? What I have in mind particularly is the rather high shrinkage allowance would that have any serious effect after welding?

MR. HOWARD: The heat-treatment of these Ni-tensyl cast irons is very similar to heat-treating the ordinary carbon steel. The iron is heated to a temperature above its recalescence point, that is, where the carbon goes into solution, and is quenched in the same manner as the steel. It may be water-quenched or oil-quenched—preferably oil because of the stress and possibility of cracking—and then the tempering is carried out afterwards, and this may be done on any range from 300° C. to 400° C., depending on the properties required. It results, due to that quick cooling, in a finer grain in the matrix of the cast iron, just as you get in the steel. You take the normalised or annealed steel, you have the large-grain size; if you quench it you obtain a smaller grain—generally quench at 850° C. and then temper about 500° C., depending on the carbon content of the steel.

As to the high duty irons for dies, I have not any personal experience of these being used. I perhaps ought not to have put it in. I have only seen it stated in technical literature, and it was stated they were used for blanking purposes, and I have taken it the way you suggest.

MR. BAILEY: One would imagine the edge would not be quite strong enough for that.

MR. HOWARD: Well, you have quite a good resistance to impact with a reasonably high tensile. As to the welding of high duty irons, it is preferable to heat before welding, and you certainly

cannot weld successfully in the heat-treated condition, otherwise there is the difficulty of cracking due to stresses, but the welding can be carried out either by arc or acetylene.

MR. RYDER: Can Mr. Howard tell us what margin of safety is allowed in adding the various ingredients to the ladle in order to arrive at a fairly consistent analysis? Also, I should like information on the use of these high duty irons for bearings and possibly spindles in machine tools. For instance, about five or six years ago I saw an American machine tool—a very good machine tool—and I was amazed to see that it had a cast iron spindle and cast iron front neck; it was pulled down for overhaul, and the whole bearing had a perfect bearing surface with a lovely blue sheen on it. What sort of iron would Mr. Howard say that was? What would be the best for bearing surfaces, and ought it to have any heat-treatment? There is the Shorter method of hardening gears. Is that applicable at all to cast iron?

MR. HOWARD: The method of adding the calcium silicide is controlled by the Meehanite Corporation; instructions are given by them, and they start the process up for you, but there is quite a reasonable latitude. Roughly, in normal melting practice in the cupola you lose .25% of the silicon—if the mixture in the cupola is 2% when you put it in, it comes out 1.75%. You can calculate from that how much calcium silicide is required. The hopper for the addition of silicide starts when the metal is in full flow—the flux won't matter. If you are within .2% or .3% it is quite enough.

The bearing and spindle is rather interesting. High tensile irons could certainly be used for that, and should preferably be used in the heat treated condition. A cast iron crankshaft which is heat treated is oil hardened at 850° and then tempered. The only thing is to inoculate this iron; this is usually a duplex process, the iron is melted in the cupola and then superheated in an electric furnace.

The Shorter process could certainly be used for hardening, but I doubt if you would get any better results than by using chills. When all is said and done, the use of chills in the foundry is quite simple, and particularly if you make use of the chilling properties of carborundum, either in the block or in the powder. On a number of our alloy iron castings—and on the high chromium iron we probably have to chill to get good castings—we have used powdered carborundum for a number of years, and used about 2% Bentonite as a binder. It will give you quite a hard surface; in fact, carborundum bricks are sold for that purpose, and some machine tool people are chilling with them.

MR. RYDER: Are they better than iron chills?

MR. HOWARD: Do you mean from the chilling effect? It is about the same.

MR. RYDER: From the final result on the job. Do you get hard spots with chills?

MR. HOWARD: I cannot say that they are any better, but they are more adaptable, and certainly it is more adaptable to use powdered carborundum. Other machine tool people are using them to a large extent, particularly on roller work.

MR. RYDER: There is one thing about cast iron for crankshafts. I have actually seen a test on a steel crankshaft and a cast iron crankshaft. They put the steel crankshaft in a special machine and put a twist on it; they turned the whole lot round at high speed, about 1,000 to 2,000 revs. I am not certain about the speed, but it was a frightening spectacle. It whipped all over the place, and everybody retired to a safe distance. Then they put the cast iron one in the same machine, gave it the same twist, and started it up, and there was no appreciable vibration. This was after heat treatment; before the heat treatment, if they dropped a crankshaft on the floor it broke.

MR. WESTWOOD: Could you tell me how the chromium in high chromium iron associates with the iron to give a non-corrosive metal, and also in non-magnetic irons is it possible to vary the magnetic properties by means of heating it alone? I saw a specimen not long ago in which one end was entirely non-magnetic and the other end highly magnetic. Can you explain briefly the process of inoculation?

MR. HOWARD: The chromium in the high chromium iron first of all combines with the carbon and forms chrome carbides, and the rest combines with the iron and forms ferro-chrome. The two offer very high resistance to corrosion. With regard to the specimen piece of steel; it is possible to do it—I have never seen it, but I believe it has been done experimentally. If you take the Staybrite type of steel, which is non-magnetic, and keep it at a temperature of about 400° C. to 500° C. for a very long time it will become magnetic, because you have converted it from the austenitic state to the martensitic state. You could make one end like that on a long bar, but I do not quite see the force of it.

The process of inoculation is merely refining the matrix of the iron and giving the solution something that the graphite flake can form on; just as though you got a solution of salt and water which was very strong, approaching saturation, and you dropped something in it that was soluble, then the whole thing would come down as salt crystals.

MR. WESTWOOD: What substances are used in this process of inoculation?

MR. HOWARD: In the case of high tensile Meehanite irons, calcium silicide. In the case of the Ni-Tensile, nickel and ferro-silicon.

MR. R. G. RYDER: With regard to inoculation, at what stage of the process is this material put in?

MR. HOWARD: For Meehanite the metal is inoculated as it comes out of the spout or just thrown into the ladle; it is preferable to drop it into the chute.

MR. R. G. RYDER: Mr. Howard mentioned superheating of the cast iron after pouring from the cupola. I would like him, if he will, to enlarge a little on that.

MR. HOWARD: Carbon in cast iron exists in two forms—combined carbon and graphite. Until you get up to the higher temperatures, say 1,500° C., you do not get all that carbon in solution. The consequence is that with the normal cupola temperature of, say, 1,400° C. to 1,450° C., some is present as graphite and some is present as combined carbon, which will result in a larger graphite flake than if you have the whole thing in solution and then come out of solution.

MR. R. G. RYDER: What is the method adopted in superheating?

MR. HOWARD: You cannot get much above 1,400° C. to 1,500° C. as a maximum in the cupola. You can get 1,600° C. in an oil-fired furnace, or you can use an electric furnace which will superheat above that temperature. For austenitic irons we make use of the Stein-Atkinson oil furnace, and pour the metal direct from furnace. I do not think the duplex method is practised at all in this country. It is practised a lot on the Continent and in America, but not many alloy irons are made in this way—the iron is melted in the cupola, transferred to the electric furnace, and then the other alloy additions made. The metal is then brought up to a high temperature and poured.

A VISITOR: Mr. Howard referred to welding by the use of monel metal. Would he please state just what kinds of cast iron he proposes to weld by this method, and what magnitude of flowing of the monel metal is best for silicon irons? Would Mr. Howard kindly tell us in what category he places what is known as cylinder quality cast iron?

MR. HOWARD: Personally, I have used monel metal for welding any type of cast iron, because there is less possible danger of hard spots; with the silica rod there is not much danger of hard spots, but you get them. The cylinder quality of cast iron would

certainly be of a quality that would meet Grade "A" of the 321 specification. Normally, I should expect to get round about 15 tons per square inch from a .875 bar.

VISITOR: What would roughly be the analysis for it?

MR. HOWARD: Approximately, 3.3 to 3.5 total carbon; silicon content of 1.4 to 1.6; phosphorus below .5; manganese 1—1.5.

VISITOR: No nickel?

MR. HOWARD: Usually the metal contains quite a proportion of steel scrap, 15% to 20%, and may contain up to 3% nickel.

MR. KEMP: Did I understand Mr. Howard to say that with a lower percentage of chromium you get harder machining than you would with a higher percentage of chromium? I have tried putting, say, 20lb. of ferro-chrome to the ton, and it was machinable; when I got to 40lb. it made it less machinable; when I got over 50lb. I could not machine. To be quite frank, I made a job for a man, adding up to 50lb., and taking a risk whether I could machine it; I just went to 50lb., and it was just machinable; I got six or seven rolls out of it; it turned out all right; he has got the extreme wear out of it, and says he has never seen a roll like it. In fact, the same man offered me £50 for this mixing, but I said: "No, it's a secret!" What I would like to know is whether it was a freak. Another point we have heard mentioned by foundrymen is that of the "burning" of cast iron. You spoke of 1,600° C.; we do very well if we get 1,220° C. or 1,250° C. out of our cupola.

MR. HOWARD: The addition of chrome up to 50lbs. to the ton, presuming it is 50% ferro-chrome, would give you about 1% chrome, and with a silicon content of 1½% to 2% that iron should just about be machinable. It would be very good for wear and also for resistance to heat. There is a firm which makes a speciality of fire bars with 1½% chrome. The chrome works in a very similar way to nickel as far as hardness is concerned; up to 1% you can machine, from 1% to 25% you won't machine at all, from 25% to 35% you can machine providing your carbon is cut down to 1½%. With nickel up to 4% you can machine, from 4% to 10% you can't machine, above 10% you can machine. The burning of cast iron is rotten cupola practice. Really, it is rotten cupola practice to do it. They do it, and it is done by playing about with air conditions—too much air and probably using poor quality iron.

At 1,250° C., if this is the temperature at which you come out of the cupola, I am afraid I do not know how you run your castings, because I can assure you that we are not tapping out

of our cupola below 1,400° C., and we do not cast anything below 1,250° C.; in fact, we have a job to make it run. Normally our casting temperature is round about 1,350° C. for any section of casting, and superheating up to 1,600° C. It must be understood that superheating is carried out in a furnace in which the metal is covered with the slag, and that protects it—that is why you do not get any "burning" of the iron, as you call it. I should be interested to know how your temperature of 1,250° C. is taken.

MR. KEMP: By optical pyrometer.

MR. HOWARD: Then there is a correction of 80° C. to 120° C. to be added, depending on the type of instrument and light.

MR. KEMP: If you put 80° C. on top of that you get a reading of 1,330° C.

MR. KING (Chairman): There is one point which particularly interested me, and that was that Mr. Howard stated that the Shorter process would give much the same result as chilling. The Shorter process is practically as old as the hills; whilst I don't say I am as old as the hills, I remember using this 25 years ago. It is a very common practice, and at that time we came to the conclusion that we really gained very little by using the flame-hardening process over the use of ordinary chills.

Another point which Mr. Bailey mentioned regarding dies. While I have not had any experience in using cast iron dies for blanking, some few years ago we used dies for forgings. In the first place we broke some steel dies which we were using for the forging of rings; we were on a very urgent job and did not know what to do. We made these dies in as good an iron as we could get—probably 20 tons—and they gave us such good results that we went on to drop forgings.

It became quite a common practice in many of the railway shops, and is still used on quite heavy drop forgings, that is, drop forgings, to use these where they need a quantity of up to 1,200 stampings, and the wear, in fact, compares very favourably with that of even high-class steel. If you go above that number, of course, then wear takes place very rapidly. Local cracking, for instance, takes place much more rapidly in a cast iron die than in steel—at least, that is our experience.

A vote of thanks to Mr. Howard concluded the proceedings.

MECHANICAL PROBLEMS IN THE SETTING OF SPIRIT-LEVELS

Paper presented to the Institution by
Frederick Grover (Member)

IT is quite understandable that with a vast armament programme in progress, the demand for precision levels outstrips the normal supplies, and users may find themselves compelled to consider ways and means of obtaining instruments which are indispensable in executing their contracts. Should they go so far as to consider the assembly and setting of their own levels, the engineer concerned finds himself confronted with a problem beyond the range of his ordinary day-to-day experience, in that the art of setting levels is normally confined to makers of the high-class precision measuring instruments associated with tool room requirements.

In an endeavour to bridge the gap the author undertook an investigation of the problems involved in the construction of levels in general, and attempted to evolve a simple technique for setting instruments of the special form described in later paragraphs. This communication comprises a short review of fundamental principles and their application to a specific case.

It may be positively stated that the bubble of a level will travel towards and come to rest at the point where the difference between the opposed end pressures is insufficient to overcome the force of cohesion between the liquid and the glass. This force is associated with the phenomenon of surface tension, and is usually discussed in that connection.

The truth of the above proposition may be experimentally demonstrated by taking four straight and similar glass tubes of about $\frac{5}{16}$ in. diameter filled respectively with ether, petrol, alcohol, and water, so that the length of the bubble is the same in each tube. These tubes are mounted side by side on a horizontal plane surface, means being provided whereby the plane may be given an inclination in minute increments. It will be found when such an increment is given that the bubble in the ether tube is the first one to move. With another step in elevation the petrol bubble is the next, followed by the alcohol bubble. That in the water tube is the last to start, but it will need a considerable elevation to effect this, unless its normal surface tension is artificially reduced. It is also apparent that the speed of the bubble

movement differs, the highest being that in the ether tube, followed by petrol, alcohol, and finally water, whose performance is decidedly poor.

The specific gravity of the fluids used was tested at 58° F., and gave the following values: Ether, ·701; petrol, ·793; alcohol, ·835.

It will be noted that in the lightest fluid the bubble appeared to be the most buoyant, and that the buoyancy as indicated by the speed diminished as the respective weights of the fluids increased. Buoyancy is, however, measured by the difference between the end pressures acting on the bubble, and the experiment described demonstrates that where the resultant upward pressure is least, as in the case of the ether tube, it is yet capable of driving the bubble along at the greatest speed.

The sensitivity of a level must, therefore, be very largely dependent on the nature of the fluid in the glass tube, although existing books of reference and other literature usually state it to be directly proportional to the curvature of the tube.

It is well understood that the bubble movement in a level tube of 20 feet radius will, for a given angle of elevation, be twice that shown in a tube of 10 feet radius for the same angle. Similarly, if the personal error of an observer using a 20 feet radius level leads to an error of 1% in his recording, an error of 2% may be expected if he uses a level of 10 feet radius, so that an increase in the radius of curvature gives the level a mechanical advantage operating in favour of the observer.

In assessing the sensitivity of a chemical balance or a heavy testing machine one is concerned with the resistance to movement caused by imperfection in the knife edges supporting the beam. Similarly, the sensitivity of the level should be measured in terms of resistance to movement of the bubble. The issue is further confused by the dangerous convention of defining the sensitivity in terms of seconds of arc, thus, with a level having a 12in. base and recording a movement of ·1in. when one end of its base is raised ·0005in. corresponding to an angle of elevation of 1/24000 radians, and since there are 206264·88 seconds in 1 radian the instrument is described as one of 8·6 seconds.

This convention is widespread and ill-understood by those who use it, and dangerous, because the divisions on the glass are sometimes marked in millimetres and sometimes in tenths or even in twentieths of an inch, and unless all are graduated alike the measure or scale of the so-called sensitivity is meaningless. It is therefore suggested that engineers should estimate the prformance or sensitivity of the level tube on the basis of its radius of curvature.

The radius is easily determined. The angle of elevation of the base of the level is equal to the angle of displacement of the bubble.

Thus. if the base is of length L and one end of the base is raised a small distance H, the angle has a sine value of H/L. If this elevation gives a deflection of the bubble measured by a length D, and if R is the radius, then D/R is the sine value of the angle of deflection. For small angles of less than two degrees the circular measure is almost identical with the sine measure, and therefore we can write $D/R = H/L$ and $R = DL/H$.

Let it be assumed that a level is required to measure a difference of ·0005 by observing the deflection of the bubble, and that the length of its base is to be 12in. Then R/D must be equal to 24,000. The question now arises as to what arbitrary value shall be given to D to minimise the personal error of observation, plus the very much smaller constant error due to bubble resistance in the sense discussed above. It is clear that if D be chosen of large value, then R will be correspondingly large. If D be made of ·1 of an inch, then R will be 200 feet. If R is 200 feet, the hydraulic head at a point situated .1 from the centre position on the bubble is of the order of 5×10^{-7}. The expansion of glass is (per degree F) of the same order of measurement. In the face of such minute differences it is obvious that a level of this radius will not only require most careful usage but will also require frequent checking and adjustment.

A surprising example of temperature effects on levels of only 6 feet radius of curvature was revealed during the process of setting some 2,000 levels. It was observed that if the tubes were touched with the finger tip the bubble promptly moved towards the point touched, but if the tubes were inadvertently pressed down by the touch the bubble should move in the opposite direction. The explanation seems to be that the heat from the finger raises a minute local blister on the glass, and the movement of fluid to fill the void thus created moves the bubble.

It was further noted that by holding the brass container near its end for half a minute the level would be quite out of truth through the heat from the hand. The disturbance fades away as the heat dissipates. It may also be noted that a level which is slightly off centre may be coaxed to read correctly by a few judicious strokes of the finger-tip over the index marks—a phenomenon of which inspectors should be acutely aware.

Considering the work to be done, the author felt the need of a level made with due regard to the points outlined in the foregoing discussion, which are:—

(1) That the sensitivity of the level does not depend entirely, if at all, upon its radius of curvature.

(2) That by extending the radius the bubble movement is, so to speak, geared by a higher ratio to the hydraulic head which causes its movement.

(3) That extension of radius is made solely to minimise observational error, and it results in greater liability to error through temperature effects.

It was felt that a level might be designed with a comparatively short radius of curvature if the necessary "mechanical advantage" could be secured by some means less susceptible to temperature effects.

In the result, the author constructed the level shown in Fig. 1.

It will be seen that the left end of the containing barrel is pivoted at a fixed height above the mild-steel base. The other end is supported on a mild-steel pillar screwed at its lower end 0 B.A. size and tapped into a swivel block pivoted on the base. Above this thread the pillar is threaded again to the size 1 B.A., and this portion screws through a sleeve (not visible in the picture), pivoted, and free to move in a hole made in the extended end of the barrel. These screws (0 and 1 B.A.) were chosen because the difference in their pitches is ·004, and therefore one quadrant of

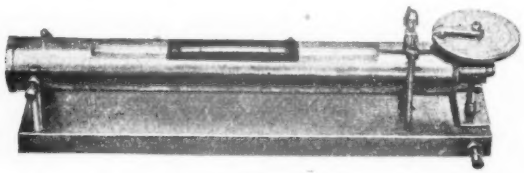

Fig. 1.

the dial above represents a vertical movement of ·001, which is a convenient basis for further sub-division. The linear distance between the quadrant marks is about 1·3in., so that if this be divided into 10 parts the height of the barrel can be altered at one end to plus or minus ·0001 by the observation of a scale in which ·0001 is represented by a distance of ·13in. And, since the distance between supports of the barrel is 9 inches, the angular displacement is ·0001/9 radius, which is equivalent to very nearly 2·3 seconds of arc. Comparing this with a direct reading level in which the graduations on the tube are separated by·1 of an inch and with a base 12in. long, the radius of curvature would have to be no less than 859 feet, whereas the level illustrated has a radius of only 37·5 feet, and its virtual base is only 9in. long. It will be noted that any tendency to backlash is obviated by the tension springs attached to the base and acting on a cross-bar spanning the barrel, which is held by a central adjusting screw. The arm terminating in the shape of an arrow may be clamped to the dial-plate in any position, and may thus be used to indicate when the

angle of elevation is zero. In using the level to measure height differences the deflected bubble is brought back into its central position and the angle of deviation determined on the dial. It is much easier to locate the bubble in central relation to the cross hairs rather than observing one end only of the bubble, which is apt to vary in length through temperature changes.

The bubble tube of about $\frac{5}{16}$in. diameter was fixed and curved in the following way:—

A straight tube about $6\frac{3}{4}$in. long was filled with ether to allow for the bubble and heat-sealed. The aperture in the barrel for exposing the top of the tube is about 6in. long. The barrel, which has a top aperture of about 6in., was drilled and tapped for a small screw in a central position diametrically opposed to the aperture. This screw is not visible in the photograph.

A small brass block was fitted to the circumference of the tube and drilled so that the screw entered it by about $\frac{1}{8}$in. By placing this block inside the empty container, and with the screw entered in the hole, the straight glass tube could be placed upon it centrally and raised by screwing up from the outside until the glass tube touched the inside circle of the container. The tube can then be regarded as a beam supported on abutments about 6in. apart, and loaded from below by pressure applied by the screw, which was tightened just sufficiently to retain the tube. This was carefully adjusted axially to admit a ·002 feeler between the tube and wall of the aperture in the container, thus ensuring freedom between the abutments. The container was then placed on a level surface plate, and the reactions of the bubble were observed. The pressure on the central screw was then adjusted so that the bubble moved towards the centre of the tube and came to rest there. By raising first one end of the container and then the other alternately, an estimate of the speed of return to the centre, as well as the symmetry of behaviour of the bubble, could be made. This being deemed satisfactory, all was ready to run in the plaster of Paris to fix the tube in the container.

Some objections may be advanced to the method of bending the tube, and may be met satisfactorily as follows:—

(a) *The glass is under stress.* This is true, but the stress is well within the elastic limit, and is not greater than that arising from temperature changes.

(b) *The curvature of a centrally loaded beam does not coincide with the arc of a circle.* This may be countered by spacing the index marks appropriately, and there is no objection to using a level progressively more responsive to angular changes, while with the design under discussion bubble

displacement can be nullified by an accurate measure of the angle required to return the bubble to its normal position.

It is by no means certain that the curvature of the tube will remain constant while the plaster is setting, and this will be appreciated in considering the behaviour of the plaster itself.

Running plaster into the open end of a container of $\frac{3}{8}$in. internal diameter presents no difficulty. If, however, the means of locating the vial involves blocking up both ends of the container, the only entry for the plaster is through the small gap between the tube and the container, which gap extends along the perimeter of the exposing orifice (see Fig. 6). If the inside diameter of the container is $\frac{3}{8}$in. and the tube ·28in., and the tube is in vertical contact with the inside top part of the container (as it should be), then the width of the gap through which the plaster must flow will not be more than ·01in., and may only be ·005in., and the question of feasibility arises. The container and tube now referred to appear in Fig. 4.

Answers were now required to the following questions on the behaviour of plaster of Paris:—

(1) What is the minimum weight of water to be added to a given weight of powdered plaster to give a mixture sufficiently fluid to run through a crack a little less than ·01in. wide?

(2) Will such a mixture set hard enough for the purpose in view?

(3) Does expansion occur during setting? If so, when does it begin? How does it progress and at what stage may minute final adjustments be made?

(4) What temperature changes will occur during mixing and setting?

With precise information on these points one could proceed with confidence and with the assurance that a level truly set at the critical moment of its final adjustment would need no subsequent correction, which could then only be done by the tedious operation of lapping the base. The time to be saved by avoiding this was considerable.

Some device for an experimental determination of these facts being obviously required, the instrument illustrated in Fig. 2 was made from available material, and proved to be well adapted for its purpose. It consists of two horizontal bars which embrace a split cylindrical mould ($\frac{1}{4}$in. diameter and $\frac{1}{2}$in. high) situated near the pivot ends of the bars. The near side bar is free on its pivot, the other fixed to the base. The mould rests upon a sheet of glass with the direction of the split parallel with the fixed bar.

A screw passing through the near side moving bar enters a well-defined recess in the near half of the mould. A similar screw in the fixed bar enters a recess in the other half of the mould and is provided with an indexed disc. The two halves of the mould are held in contact by the light pressure of an adjustable tension spring spanning the bars. On the fixed bar there is a steel piece fastened to it at right angles, extending inwards and reaching a little beyond the centre line of the instrument. This serves as a platform for a roller ·08in. maximum diameter. A long pointer is fastened to the roller, the whole being counterbalanced to oscillate equally about the vertical and come to rest vertically.

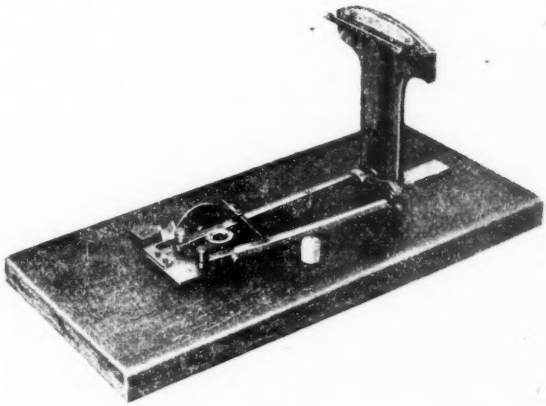

Fig. 2.

The central section of the roller is reduced in diameter, trinnion fashion, and a light spring finger pivoted on the moving arm rest on the reduced diameter. A scale is provided which can be viewed from above by reflection from a mirror on angle brackets. Incidentally, it may be noted that reflection doubles the parallax, which aids the observer and brings the image of the scale into a convenient position for observation.

The instrument was calibrated by means of a screw and index plate, which involved a slight movement of the whole of the mould resting on glass. In use, however, any expansion of the contents of the mould only moves one half of it. Liquid plaster can be run into it without escape through the joints, and when set is easily removed. The white object shown in the photograph is a typical cast, which is of hard and close texture.

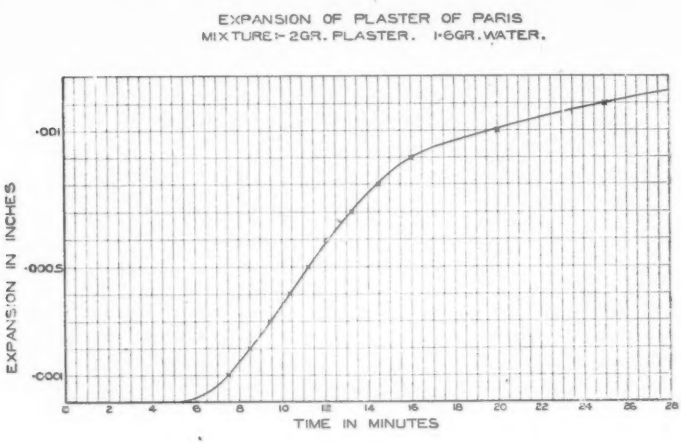

Fig. 3.

Many preliminary experiments were made, yielding consistent results, proving reliability, and establishing confidence. Examination of a typical curve plotted on a time base (Fig. 3) reveals the following facts: —

1·6 grammes of water is added to 2 grammes of plaster, stirred vigorously for 15 seconds, and then poured into the mould. Zero time is taken as the moment of adding the water. The following points are noted: —

(1) Expansion begin after the lapse of about 6 minutes.

(2) In 8½ minutes the expansion is ·0002in.

(3) Expansion then proceeds at a nearly uniform rate of increase of ·0001in. per minute up to the 13th minute.

(4) From this time onwards the rate falls off, and at 28 minutes it amounts to ·001in. When left overnight, by which time the plaster is hard, the pointer would show up to ·0012in.

The maximum expansion recorded in any of the tests was ·0015in.

After the plaster had set the mould could be removed and measured with a micrometer, and again after the block was removed from the mould. This direct measurement roughly agreed with the expansion recorded by the extensometer, although the micrometer used did not admit of positive readings to ·0001in. Since the mould used was ¼in. diameter inside, the maximum expansion of this particular mixture is ·003 per inch of length.

Practical work in adjusting tubes whilst the plaster is setting showed that it was still possible to make minute adjustments to the tube up to the 10th minute, and if such were made at this time the setting could be regarded as permanent.

It was found that with this weight of mixture, namely, 3·6 grammes, just enough to set one level, the maximum rise in temperature was 11° F., and that when the critical time of adjustment was reached the heat was sufficiently dissipated as not to affect the level.

Reverting for a moment to Fig. 1 and the setting of the tube, some doubt was expressed as to its ultimate curvature after the plaster had hardened. The depth of plaster between the inner wall of the container and the outer wall of the glass tube is about $\frac{3}{16}$in. The expansion would therefore be about ·001in. Exactly what pressure is exerted by it on the tube it is impossible to say, but we can well conceive that the tube may be in the posture of a beam uniformly loaded, and that the uniform pressure will tend to modify the curvature.

Fig. 4.

A careful determination of the radius gave 37·5ft. when observations were confined to ·2 on both sides of the central position. Measurements taken beyond this point were progressively augmented on both sides, showing the curvature to be slightly flattening towards each end. As the level is only indexed for its central position, and angles of deviation are measured by turning the dial until the bubble is restored to its central position, which can be very accurately observed, and since one second of arc will perceptibly deflect the bubble, it can be relied upon to measure a difference in height per foot of ·000058in.

The technique evolved by the author for setting the levels illustrated in Fig. 4 in their containers can now be described.

The setting requirements for these levels are somewhat unusual in that the bubble must register correctly while the instrument is swung through 45° in either direction about its long axis. This, of course, implies that the effective axis of the glass level tube must be not only parallel to the base, but must also be coaxial or parallel to the axis of the instrument. The only possible formation of bubble tube to satisfy this condition is that of a barrel. If it is otherwise it will have maximum curvature in the vertical

plane, where the hydraulic head is greatest, and there will be no such head when the tube is rotated about its axis through an angle of 90°.

The bubble tubes were obtained from makers, and, although supposedly of standard pattern, showed differences in performance. There were variations in diameter, but lengths and index marks were uniform. The bubbles themselves varied in length, some being well within the index marks and others beyond. Those with short bubbles responded more quickly to change in elevation than did the longer ones. This confirmed experiments made with two straight tubes of equal diameter ($\frac{5}{16}$in.), both filled with alcohol so that one of the bubbles was about twice the size of the other. When the tubes were equally inclined side by side the small bubble travelled upwards faster than the large one. A like experiment made with two glass tubes of unequal diameter, but with the same length of bubble, showed that the bubble in the larger tube moved faster than that in the smaller one, and tubes of larger diameter with minimum-sized bubbles were particularly lively.

In trying to predict the behaviour of the tube before insertion in the container, and to obtain the offset required, it was placed on a surface plate and rolled about its axis until a feeler could be inserted between surface plate and tube. Sometimes a ·004in. blade would enter; at other times even a ·0015in. blade could not be inserted. In a few cases tubes set to read level, when tested for speed of action, would return slowly to the centre from one end, but when similarly tested in the reverse direction the bubble would remain at the end, showing this unresponsive end to be actually tangential to the curve on the responsive end. Some tubes which were apparently straight on the outside behaved quite satisfactorily when set, and may have been ground to barrel shape on the inside, which practice is often employed by makers of high-grade levels. These observations extended over a period of 12 months, during which time over 2,000 levels were treated. Needless to say, the endeavour to predict the behaviour by quick inspection failed, and it was found better to get on with the work, rejecting the failures.

The jig illustrated in Fig. 5 was made to conform with the requirements, and it will be noted that the container is screwed to the levelling platform, which consists of a substantial angle piece, pivoted and clamped either in a horizontal or inclined plane at 45°, stop pins being provided for location. The supporting angle bracket rests upon a face plate fitted with three levelling screws, and stands on a thick plate glass sheet (to avoid indentation of the screws) which was set in plaster on the bench. A mirror was mounted at the rear, so that the level, when set, could

be observed after being turned end for end. The bases of the containers were milled and lapped and a $\frac{3}{8}$in. hole was drilled and reamed through the body as nearly parallel to the base as possible. Suitable end covers were fitted and fixed with taper pins, these parts being removed for the insertion of the tube.

The problem of locating the tube in the container, of making the necessary adjustments to give accurate readings while it was

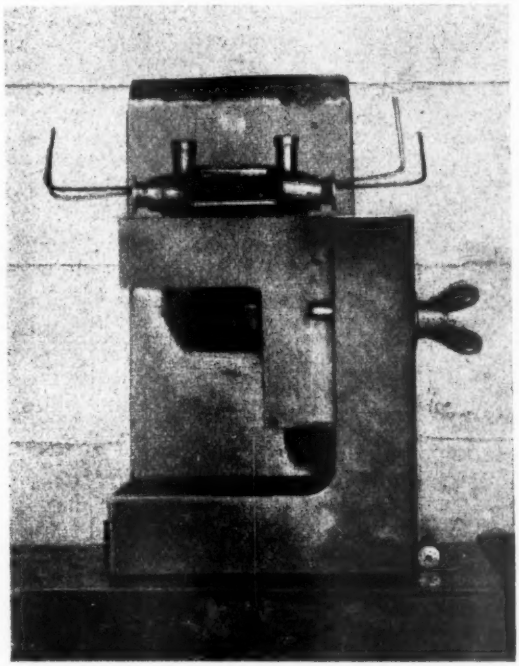

Fig. 5.

temporarily held between end supports, and providing for the easy withdrawal of these supports after adding the plaster, was solved in the following manner.

Two spare solid end covers were bored parallel so as to leave a wall about ·015in. thickness (see Fig. 6). Two opposed holes, $\frac{1}{16}$in. diameter, were drilled in the wall, which was then divided into four equal segments by saw cuts reaching to the flanged

ring, thus providing end pieces sufficiently resilient to ensure an easy but steady "push" fit in the containers. The end pieces were then filled with a plug of plasticine made to protrude about $\frac{1}{8}$in., the protruding end being coned as shown in the illustration. By squeezing the plasticine it became keyed into the holes in the wall, while the four slots, which were cleared of plasticine, acted as air vents when running the plaster.

By reference to Figs. 5 and 6 the following procedure will be understood. The empty container is cleared of all particles of dust and then screwed down on the levelling platform of the jig, which is scrupulously cleaned. The inside of the container is wetted with water by drawing through it a bunch of pipe cleaners screwed up at one end for easy entrance, the other being

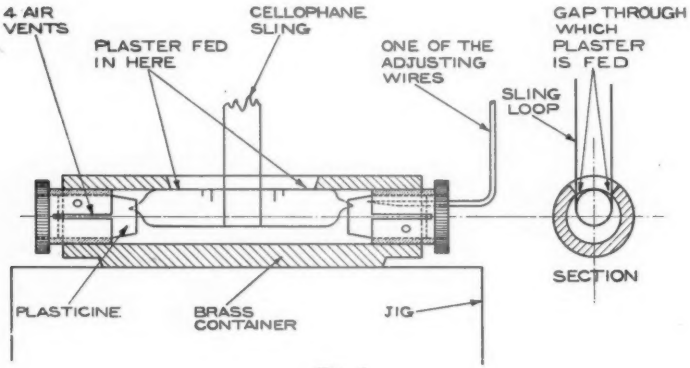

Fig. 6.

splayed out and wetted. The film of water left on the wall acts as a flux for running the plaster. A strip of the thinnest cellophane about $\frac{1}{4}$in. wide and about 5in. long is then inserted through the slot in the container. The bubble tube is then inserted endwise over the cellophane. The two plasticine nipples are then pushed a short distance into the container, and the cellophane, which now acts as a sling, raises the bubble tube until the ends of the tube contact the inner circumferential surface of the container. The sling is manipulated between the finger and thumb to bring the index marks into the required position both laterally and circumferentially. With the tube in this position the end nipples are gently pressed home until the pips of glass enter the plasticine, just, and only just, enough to retain the tube when the sling is released and withdrawn.

All is now ready to effect the adjustment of the bubble, and for this purpose four steel wires about $\frac{1}{16}$ in. diameter are necessary, and these are bent for convenient handling, as illustrated. The entering end of the wires is made wedge-shape to a sharp edge, with the flat side of the wedge opposite the upturned end of the wire.

The levelling platform is clamped in its horizontal position and the high end of the bubble is observed, and at that end one of the wires is thrust into the plasticine plug at its periphery and in line with the tube axis until the bubble begins to move towards its central position. The platform is then swung over to its maximum inclined position. If there is no movement of the bubble during this motion one knows that the tube is coaxial with the pivot about which the movement is made, and therefore no adjustment is required in this plane. If there is a movement, however (and this usually happens), another wire is pushed into the plasticine plug at the high end in that plane, so as to move the tube in a direction parallel to the inclined plane without affecting the previous vertical adjustment. A return to the horizontal plane will generally show that some vertical displacement has occurred despite every care to the contrary, and further adjustment requiring the insertion of a third wire is made. By the time the correct position is found, four wires may be employed—two for the horizontal and two for the inclined plane. In Fig. 5 the four wires are seen when the level has been adjusted ready for running the plaster.

The successful application of the method described depends greatly on the condition of the plasticine, which must be such as to yield responsively (at the conical ends protruding to support the tube) to the delicate inward thrust of the adjusting wires. It will be noted that the preliminary location of the tube by means of the sling made it contact the metal container so that any adjusting movements must take place in a downward direction, and that the position of all the wires left in for a final adjustment would tend to a further downward movement after the plaster is run in. The significance of this procedure is that in making the final adjustment at the critical moment the tube is forced more deeply, however minutely, into the plaster, and so aids rigidity when the plaster has set.

In about 15 minutes after running the plaster the wires can be withdrawn and the plasticine nipples gently pulled out. It will be seen that the plaster has filled the end cavities as far as the plasticine would allow. The indentations in the supporting cones of the plasticine are then rolled out by hand, and the interior of the plasticine need not be disturbed until usage has rendered it inoperative. They are then ready for the next setting. To facilitate the

preparation of the plaster for each cast it is convenient to pick up the water in a suitable syringe and so fill a water-measuring tube up to the gauge mark. The plaster can be measured by volume (if done with discretion in regard to density of the powder) by means of a split container of the right size, each half of which may be attached to the ends of an old pair of scissors, thus affording easy manipulation in one hand. The mixture can be stirred with the glass syringe already mentioned, which should have a ring attached to its piston for easy manipulation in one hand. After stirring for a few seconds the liquid is drawn up into the syringe and then gently fed into the container of the level tube in positions indicated in Fig 6, care being taken to keep the plaster away from the index marks on the level tubes. It will be found that a mixture consisting of 1·6 grammes of water with 2 grammes of plaster will drain through the small gap between the glass and the container until it begins to well up and ooze about the centre portion of the tube. Some slight disturbance of the bubble may occur, due to temperature effects, but in about 10 minutes, which is the critical time for making the final adjustment, the temperature will be uniform, and adjustments then made may be regarded as final. It is advisable to allow 24 hours for the plaster to thoroughly harden before making the final inspection. A sharp penknife blade is used to clear the tube of dried plaster, and the glass polished with a wad of clean cotton wool. When the ends of the container are filled with plaster just sufficiently to cover the pips on the ends of the tube, and the end covers replaced, the setting is complete. The rate of output with one jig in use is limited chiefly by the time allowed for the plaster to set, but studied routine will enable an operator to complete with ease three assemblies per hour when he has mastered those small points of technique which emerge from observation and experience.

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ANNEALING, CASE-HARDENING, QUENCHING.

Design and Heat Treatment, by D. Macpherson. (*Machinery, February 5, 1942, Vol. 60, No. 1530, p. 61; 6 figs.*)

There are two types of stresses which combine to cause fracture of a part in operation: (1) the external stress of service conditions, and (2) the internal stresses set up in fabrication and heat treatment. Effect of temperature gradient for parts of non-uniform or complex section. The importance of uniform quenching. Illustrations: Faulty design of plug gauge without blending radius. Gear burnishing tool with sharp corners at the roots of the teeth. Correct and incorrect design of keyways. Undercutting form tools, &c. Considerations in die design. Stress raisers. Stress spreading. Some examples of parts designed to facilitate heat treatment.

Controlled Oil Quenching. (*Wild-Barfield Heat Treatment Journal, September/December, 1941, Vol. IV, No. 30/31, p. 56; 1 fig.*)

The importance of maintaining quenching oil at a steady temperature is often overlooked. In addition to danger of scrapped work, oil loss is so much the greater if high oil temperatures are allowed to be reached, a point which is of utmost importance under the present circumstances. The automatically controlled oil cooler marks a definite step to overcome these difficulties. General arrangement of the "Prestcold" evaporative oil cooler.

Oxyacetylene Flame Hardening, by F. G. Magrath. (*The Machinist, February 21, 1942, Vol. 85, No. 48, p. 1134; 8 figs.*)

To get the best out of flame hardening the correct procedure must be followed. The position usually recommended for the heating tip. Auxiliary quenches when the work is overhead and the integral quench falls away. On some thin sections an auxiliary quench ahead of the flame may be advisable. Side quenches prevent softening of the previously hardened surface in progressive flame hardening. For protecting the work area previously hardened shields are arranged. For limited quantities standard welding equipment may be used with improvised fixtures on regular shop machines. Control of overlap.

BELTS, ROPES.

The Application of V-Rope Drives—II, by H. Stuart Jude. (*Power Transmission, February, 1942, Vol. 11, No. 121, p. 31; 2 figs.*)

Outline of the factors governing the installation of a V-rope drive. The speed ratio. Pulley diameters. Centre distance. Arc of contact. Horse-power correction factors. The rope section. Strength and number of ropes required. Horse-power capacity of V-ropes. The rope length. Fully worked example.

COMBUSTION FURNACES.

Furnaces for Production Heat Treating, by Rupert Legrand. (*The Machinist, February 21, 1942, Vol. 85, No. 48, p. 1151; 6 figs.*)

The round-up of heat-and-move heat-treating equipment goes on with descriptions of walking-beam, shaker-hearth, and semi-continuous furnaces.

COOLANT, LUBRICANT.

Non-ferrous Electric Melting Furnaces, by J. McAfee. (*The Australasian Engineer, November 7, 1941, Vol. 41, No.306, p. 120; 11 figs.*)

Electric furnaces used for melting non-ferrous metals may conveniently be divided into three groups: (1) arc furnaces; (2) induction furnaces; (3) resistance furnaces. The Detroit rocking arc furnace. Furnace movements in melting cycle. Boiling point and pouring temperatures. The Ajax-Wyatt induction furnace. The circuit diagram. The thermionic valve circuit. Motor generator circuit. The convex meniscus. The resistance furnace. Crucible furnaces. The hearth-type resistance furnace.

Lubrication in the Working of Metals, by H. N. Bassett. (*Met. Ind., Lond., January 2, 1942, Vol. 60, No. 1, p. 2.*)

A survey of the properties and functions of lubricants used in cutting and grinding (cutting fluids and soluble oils), wire drawing, and press-working. Causes and prevention of dermatitis are briefly discussed. (*Supplied by the British Non-Ferrous Metals Research Association.*)

Coolant and Washing Systems. (*Aircraft Production, March, 1942, Vol. IV, No. 41, p. 237; 8 figs.*)

Choice of systems. A battery of six grinding machines fitted with a centralised coolant, clarifying, and distribution system. Micrographs illustrating the results obtained when grinding with dirty and clean coolant. A self-contained unit for the batch recovery of cutting oil. It comprises a heating tank and centrifugal purifier. A composite cross-sectional view of a centrifuge bowl for purifying and for clarifying. Grinding, honing, and lapping. Layout for lathes. Wash booth system. The De Laval self-contained Parawash cleaning booth.

EMPLOYEES, WORKMEN, APPRENTICES.

A Survey of the Problems of the Employment of Women in War-time, by Pamela J. Gauntlett. (*Labour Management, February, 1942, Vol. XXIV, No. 257, p. 23.*)

Four million women are needed. Dilution and training. Wage problems. Working hours. The problem of shopping. The provision of canteens. The care of children. Transfer to essential work. The need for co-operation.

MACHINING, MACHINE TOOLS.

Wheels for Thread Grinding, by A. Rousseau. (*The Machinist, February 14, 1942, Vol. 85, No. 47, p. 1081; 2 figs.*)

Precision or high production? These are only two of the many factors that affect grinding wheel selection and application. Two different types of bond, vitrified, and resinoid. Vitrified wheels should be selected where accuracy of lead is a primary requisite. However, vitrified wheels are likely to fail if pushed even slightly beyond their capacity. Resinoid bonded wheels hold their edge better, particularly on high production work held to commercial tolerances. Being less rigid, they are more

likely to follow a lead error in a pre-cut thread. Maximum operating speeds recommended by Norton Company. Effect of stock to be ground. Relationship of grit size to root width. Where low speeds are best.

Broaching of Rifling in Cannon, by H. F. Safford. (*Mechanical Engineering, U.S.A., February, 1942, Vol. 64, No. 2, p. 113; 10 figs.*)

Standard methods of machining rifling grooves. Single-hook cutter. Adjustable cutter head. Disk-broach method. Details of the disk broach. Pull-bar broach is the latest development. Rifling the 37mm. cannon. Broaching the 20mm. gun. The disk-broaching and pull-bar-broaching methods have been materially improved and modernised. The single-hook cutter with automatic indexing is still widely used, although slower than pull-bar broaching.

Production and Use of Large Spiral-bevel Gears. (*Engineering, Jan. 30, 1942, Vol. 153, No. 3968, p. 87; 2 figs.*)

A Gleason 60in. spiral-bevel generating machine installed at one of the works of Messrs. David Brown & Sons (Huddersfield), Ltd., Huddersfield. The gear teeth are of the "spiral" type, being oblique and curved, the teeth being formed by a planogenerating process. Wheel and pinion shown form part of a combined bevel-gear and helical-gear reduction unit, transmitting 1,300 h.p. with a speed reduction from 5,100 r.p.m. to 264 r.p.m. The faceplate of the machine, with its indexing mechanism, is employed for the process of heat treating the tooth surfaces. This process is shown in operation, and is employed for certain purposes in which high powers are transmitted.

MANUFACTURING METHODS.

The Bristol Hercules, by J. A. Oates. (*Aircraft Production, March, 1942, Vol. IV, No. 41, p. 243; 34 figs.*)

Part II. Production of the master connecting rod, airscrew shaft, and cylinder head: the sleeve ball and housing.

How Airacobras are Built, by O. L. Woodson. (*The Machinist, February 21, 1942, Vol. 85, No. 48, p. 1145; 23 figs.*)

The Witter Shell-forging Process, by John H. Loux. (*Mechanical Engineering, U.S.A., February, 1942, Vol. 64, No. 2, p. 123; 11 figs.*)

The fundamental elements of the Witter shell-forging process are a heating furnace, a press or upsetter for forming the billet into a pierced blank, and an Assel cross-roll mill. Illustrations show: Layout of shell-forging plant for Witter process. Double-turret forming and piercing press for 75 to 105mm. shell. Assel cross-roll elongator mill. Feed end of cross rolls where billet enters. Control side of Assel mill. Pierced blank made in double-turret press. Cross-section of 75mm. shell forging after passing through finishing mill. 75mm. shell before and after correction for eccentricity in finishing mill.

Forging 155mm. Shell Bodies, by F. G. Schranz. (*The Machinist, February 7, 1942, Vol. 85, No. 46, p. 344E; 16 figs.*)

The Manufacture of Precision Measuring Tools, by A. E. Morrison. (*Machinery, February 12, 1942, Vol. 60, No. 1531, p. 81; 6 figs.*)

Part sectional view of a 1in. micrometer. Micrometer tolerances. The flatness of the measuring faces must be within 0·00005in., and the parallelism of these faces within 0·0001in. The zero reading must be within 0·00005in. and the range of error of the traverse or pitch of the screw must be within 0·0001in.

Improvements in micrometer screw design. Diagram of square showing application of 1lb. load for rigidity test. Inspection of micrometers. Checking system. Try squares and straight edges.

Manufacture and Processing of Aluminium and its Alloys, by Paul P. Zeigler. (*Mechanical Engineering, U.S.A., February, 1942, Vol. 64, No. 2, p.106.*)

Aluminium alloys are pre-eminently suited for applications where the conservation of weight is an important factor. Indeed, their application is so extensive in the aircraft industry that aluminium has come to be known as the airplane metal. Strengthening of aluminium. Common alloys. Strong alloys. Remelting. Table 1: Nominal composition of wrought aluminium alloys; copper, silicon, manganese, magnesium, chromium. Table 2: Typical mechanical properties of wrought aluminium alloys; tension, hardness, shear fatigue. To combine the great strength of strong alloys with the excellent corrosion resistance of the pure metal a product called "pureclad" has been developed. Pureclad consists of a strong-alloy core between two films of high-purity aluminium.

Feeds and Speeds for Milling with Carbides—Part I and II. Reference Book Sheet (*The Machinist, February 14, 1942, Vol. 85, No. 47, p. 1095*).

Table of cutting speeds for: Cast iron, soft; cast iron, medium; cast iron, hard; malleable iron (free cutting); cast steel (free cutting); low carbon steel, soft; low carbon steel, medium; low carbon steel, hard; brass; ordinary bronze; aluminium. Table of feeds (per tooth per revolution) for tungsten carbide, face milling-cutters for cast iron, malleable iron, brass, bronze, aluminium, steel. Power required for milling.

Salvaging Worn Parts. (*Aircraft Engineering, February, 1942, Vol. XIV, No. 156, p. 53; 3 figs.*)

The practical methods include electro-deposition, "fescolizing," bronze welding, and metal spraying. The electro-deposition process is generally applicable to the majority of metallic articles. Hard chromium-plating plant. Fescolized airscrew blades and spiders. Worn motor-car spline shaft restored by the Fescol process. Bronze-welding is an outgrowth of the older process of brazing. The basic theory of the process lies in the fact that molten brass or bronze will flow on to the properly heated and fluxed surface of metals of a higher melting point to give a bonded or molecular union that has excellent strength. The applications of metal-sprayed coatings are very many and varied, and while many are used for protective coatings to counteract corrosion and erosion considerable steps have been taken in the last few years in the building up of worn parts. As metals different from the base metals can be applied it is possible, and is quite frequently done, to deposit a harder and more durable metal than the original on the bearing surface.

Liaison between Design and Production, by A. J. Schroeder. (*Aircraft Engineering, February, 1942, Vol. XIV, No. 156, p. 57; 2 figs.*)

Designer and engineer. Lessons from statistics. The illustrations are based on the result of more than 1,150 drawing alterations and modifications which had to be carried out in the space of about three years. The mistakes observed in those drawings are divided in both charts into 10 main groups for simpler criticism and easier analysis. Economic production will be possible only if the designer pays the greatest attention, during the actual design, to both quality of materials and methods of production, and to aspects affecting machining in the workshop. Designer and production engineer are united with one another for the good of the works, and depend on one another.

MATERIALS, MATERIAL TESTING.

Substitute High-speed Steels. (*Machinery, February 19, 1942, Vol. 60, No. 1532, p. 108.*)

The necessity for limiting the use of tungsten in high-speed steel. The suitability of molybdenum as a substitute. The characteristics and heat treatment of molybdenum cutting tools. Two typical grades are allowed: —

	Substitute "66"	Substitute "94"
Molybdenum	5.0—6.0	8·5—9·0
Tungsten	5·5—6·5	3·5—4·5
Chrome	4·0—5·0	3·5—4·5
Vanadium	1·25–1·50	1·25–1·50

The percentage of high tungsten high-speed steel and high-speed containing cobalt permitted to be manufactured will be strictly limited. Forging should be done between 1,040° C. (1,904° F.) and 1,120° C. (2,048° F.). In no case should it be continued below a temperature of 900° C. (1,652° F.). For annealing follow exactly the same procedure as at present used for high tungsten high-speed steel with a temperature between 820° C. (1,508° F.) and 840° C. (1,544° F.). The recommended hardening temperatures for both types are: pre-heat between 820° C. (1,508° F.) and 870° C. (1,598° F.), harden at between 1,200° C. (2,192° F.) and 1,280° C. (2,336° F.). Quenching for hardening can be done either in oil, air, or molten bath. If the latter is used, the temperature of the bath should be maintained at about 550° C. to 580° C. (1,022° F. to 1,076° F.). Tempering should be carried out immediately after hardening, generally between 540° C. (1,004° F.) and 590° C. (1,094° F.). The general method resembles that for high tungsten high-speed steel, with recognition of the facts that hardening temperatures are lower and care is necessary to avoid decarburisation. Hints are given on straightening after hardening, tempering, grinding after hardening, segregation of scrap. All steel-makers will adopt the standard designations of "Substitute 66" and "Substitute 94."

Heat Treatment of Molybdenum High-speed Steels. (*Machinery, February 5, 1942, Vol. 60, 1530, p. 57.*)

Molybdenum high-speed steels have a tendency to develop a soft surface when heated to the hardening temperatures. Because of this it is important to exercise certain well-established precautions to protect the surface of these steels. This can be accomplished by (1) the application of protective coatings; (2) controlled-atmosphere methods; (3) salt-bath furnaces. Procedure for salt-bath hardening. Effect of salt-bath hardening.

The Diamond at Work. (*Industrial Diamond Review, February, 1942, Vol. II, No. 15, p. 11.*)

A chart showing the various uses of industrial diamonds.

Observations on the Metallurgy of Copper-Lead and of Lead Bronzes for Aircraft Engine Bearings, by F. Bollenrath. (*Metallwirtschaft, October 31, 1941, Vol. 20, No. 44, p. 1063.*)

Discusses factors affecting production of sound castings; distribution of Pb; segregation of Pb. As regards composition, author holds view that about 20% Pb is optimum, 18-24% being the favourite range, sometimes with addition of Sn or Ni, though R. W. Dayton is said to have referred to American steel-backed bearings containing 25-40% Pb and

less than 1% Sn, cast at 1,200° in a reducing atmosphere. An excellent British engine is said to have bearings of 74 Cu, 24 Pb, 2 Sn or 74 Cu, 18·25 Pb, 8·25 Sn.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Classification of Copper and Copper Alloys—Part III, by H. J. Miller. (*Metallurgia, December, 1941, Vol. 25, No. 146, p. 51.*)

The conclusion of a paper presenting a simplified method of classifying Cu and its alloys, intended to assist engineer users and designers in specifying materials. This part gives tabulated data on materials for welding. bronze welding, brazing and Ag soldering; wrought nickel silvers; Cu-Ni alloys; Si bronzes. Parts I and II were published in ibid., October, 1941, Vol. 24, No. 144, p.178, and November, 1941, Vol. 25, No. 145, p.16.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Light Metals and Steel as Materials, by E. H. Schulz. (*Stahl u. Eisen, December 11, 1941, Vol. 61, No. 50, p. 1121.*)

A general discussion of the respective fields of application (and competition) of steel and of light metals (almost exclusively Al and alloys). Written from the point of view of the steel industry. Includes brief reference to mechanical properties and corrosion resistance.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Aircraft Engineering Data Sheet No. 7. (*Aircraft Engineering, February, 1942, Vol. XIV, No. 156, p. 56.*)

Mechanical properties of light alloys.

Beryllium as a Light Metal Component. (*C. B. Sawyer, The Metallurgist (supp. to Engineer), December 26, 1941, p. 48.*)

The Brush Beryllium Company (U.S.A.) has developed methods of production of the metal of guaranteed purity 96%, which may be raised to as high a value as 99·94%. Sawyer and Kjellgren recorded the properties of 99·5% beryllium, the impurities being aluminium, iron, magnesium, carbon, and silicon. Its density was 1·84, specific heat 0·475, and linear coefficient of expansion $13{\cdot}3 \times 10^{-6}$. In the cast condition it had a tensile strength of 7·6 to 9·3 tons per square inch, and elongation nil. As forged at 900-1,000° C. (0·75in. to 0·36in. diameter), its tensile strength was 13·3 tons per square inch, and, after annealing at 1,000° C. in hydrogen, 12·0 tons per square inch, the specimens in both cases breaking with no measurable elongation. Determinations of the modulus of elasticity gave results varying from $42{\cdot}6 \times 10^6$lb. per square inch for the cast alloy to $36{\cdot}8 \times 10^6$lb. per square inch for the forged and annealed bar. The only practical use suggested for the pure metal is to replace aluminium as "windows" for X-ray tubes, beryllium being said to be 17 times as penetrable to X-rays as is aluminium.

In general the alloys possessing a moderate elongation have nothing in their favour except a high modulus of elasticity (14 to 16×10^6lb. per square inch, as compared with about 10×10^6lb. per square inch for aluminium alloys). This is not sufficient to compensate for their lower strength at room temperature, though at 600° Fah. their tensile properties are more favourable. There are also serious casting difficulties and the author concludes that there is no future for Be-Al alloy.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)

Fatigue of Metals, by H. S. West. (*The Australasian Engineer, November 7, 1941, Vol. 41, No. 306, p. 127; 10 figs.*)

Definition of fatigue. Fatigue strength. Relationship between fatigue strength and tensile strength. Diagnosis of fatigue failures. Typical fatigue fractures. A fractured spline shaft. Typical fatigue cracks. Microscopical examination. Stress raisers. Fatigue strength in unmachined condition. Corrosion fatigue. Fatigue failure due to identification mark. Detection of fatigue cracks. Whiting method. Etching method. Luminescent method. Magnetic methods.

Synthetic Rubber, by O. M. Hayden. (*Mechanical Engineering, U.S.A., February, 1942, Vol. 64, No. 2, p. 109; 1 fig.*)

Synthetic rubber has won this position of vital importance because, with the types that have been produced, innumerable products can be made that are vastly superior to those made from natural rubber; and of perhaps greater importance is the fact that products made from it possess properties which permit the design and operation of mechanisms that would otherwise be impossible. History of synthetic rubber development. Synthetic rubbers produced in United States. Production capacity in United States. Superior properties, not price, will determine peace-time use of synthetic rubber. Uses of synthetic rubber. Synthetic rubber for automobile tyres. Miscellaneous applications of synthetic rubber.

Rubber. (*Automobile Engineer, January, 1942, Vol. XXXII, No. 419, p. 15; 8 figs.*)

Natural rubber only forms the subject of the researches referred to, there being no reference to the synthetic components. The particular investigations covered are those by the United States Rubber Co. These researches were directed primarily to the question of dynamic and static fatigue. Hitherto the attention of the physical laboratories has been principally focused upon dynamic problems. Static fatigue as affecting stocks and bonded components is found to be equally important. Test results and the deductions therefrom are given in detail.

MEASURING METHODS, APPARATUS.

Thermo-electric Pyrometry, by R. A. Dunkley. (*The Australasian Engineer, December 8, 1941, Vol. 41, No. 307, p. 14; 6 figs.*)

Pyrometry comprises: (a) thermo-couple, (b) sensitive detector, (c) leads to join these two. Thermo-couple: Platinum/Platinum-Rhodium÷maximum, recommended, 1,400°C.; maximum, special conditions, 1,500/1,700° C.; maximum, normal, 1,300/1,350° C. Chromel-alumel÷maximum recommended, 1,200° C.; maximum, special conditions, 1,400°C.; maximum, normal, 1,050/1,100°C. Iron constantan÷maximum recommended, 800°C.; maximum, normal, 700°C. Usual type of pyrometer stem. The pyrometer circuit. Pyrometers for die-block temperatures. Sensitive detectors are of three main types: (a) indicating; (b) recording; (c) regulating, or any combination of these three. Indicators may be of pivoted or suspended types. Cold junction control. Buried junction. Pyrometry outside the metals industry. Temperature of molten steel is measured by (1) a suitable thermo-couple for the maximum temperature of 1,700°C.; (2) a protected sheath capable of being immersed in molten steel for a sufficient period to take a reading. The operation of taking readings of molten steel with this apparatus calls for the combined efforts of several skilled operators.

Some Developments in Electrical and Optical Instruments. (*The Engineer, February 6, 1942, Vol. CLXXIII, No. 4491, p. 124; 5 figs.*)

"Giant Indicator." Potentiometric titration outfit. Extrusion speed indicator—all three made by the Cambridge Instrument Co. Universal measuring projector. Projection head—both made by Adam Hilger Ltd.

PLASTIC MATERIAL.

Shear Strength of Moulded Plastic Materials. (J. Delmonte, *British Plastics, Vol. 13, No. 149, October, 1941, p. 134.*)

The punch and die are described in the measurement of shear strength upon moulded plastic parts as a useful tool for a rapid method of evaluating this property by moulders. Test results upon phenolics and ureas which have been cured for different periods of time are described. It is pointed out that differences in shear values of moulded phenolics are augmented by several minutes immersion in acetone, whereas boiling water may be used to reveal substantial variation in the cure of moulded urea parts and their shear strength. Comparative tests upon a large number of injection-moulded pieces produced in the same mould are outlined, and a table prepared comparing these materials with respect to shear strength. Injection mouldings of polyvinyl chloride-acetate and polymethyl methacrylate proved to be the highest. Further tests designed to show the utility of the punch and die reveal data on the shear strength of moulded plastics as function of temperatures from 0° to 300° F.

(*Communicated by the D.S.I.R., Ministry of Aircraft Production.*)

PSYCHOLOGICAL INVESTIGATION.

Psychology as Applied to Engineering, by Charles S. Myers. (*Journal of the Institute of Civil Engineering, February, 1942, Vol. 17, No. 4, p. 296.*)

Contemporary knowledge of psychology applied by scientifically controlled methods to relevant problems in the fields of medicine, education, and æsthetics; æsthetics and engineering. The machine and its operative. The physical environment of the operative. Engineering and management. Industrial psychology and scientific management. Psychology and incentives. Psycho-neuroses and occupational life. Psychology and time-study. Psychology and individual differences. Vocational guidance and selection. Psychology and training. Crying need for closer co-operation in the future between the engineer and the psychologist.

SMALL TOOLS.

Diamond Tools, by Paul Grodzinski. (*Aircraft Production, March, 1942, Vol. IV, No. 41, p. 229; 20 figs.*)

Part I. Cutting angles for lathe work; methods of mounting, and types of holders. Special forms of cutting edges. Customary diamond shapes for tools: single point, multiple facet, and round nose. Structure of work surface. Cutting edges and angles. Point angle. Quality. Mounting the diamonds. Cold-set mounting. Multi-facet diamonds. Adjustment of turning tools. Cutting speeds for diamond tools. The Winter-visor.

Critical Speeds for Carbides, by R. H. McCormick. (*The Machinist, February 14, 1942, Vol. 85, No. 47, p. 1090; 6 figs.*)

Best results are obtained with carbide-tipped tools when the correct cutting speed is used. The roughness of the cuts made at too slow speeds is caused by a "built-up" edge on the tool. As the speed is increased the

built-up edge phenomenon disappears, and the cut becomes clean. The speed at which the cut becomes clean is commonly called the "critical," or minimum speed. Illustrations. When cutting speeds are too high the work assumes a shiny or glazed appearance.

SURFACE, SURFACE TREATMENT.

Silver to Replace Nickel and Chrome Plate, by A. Bregman. (*Iron Age, November 13, 1941, Vol. 148, No. 20, p. 59; November 20, 1941, Vol. 148, No. 21, p. 52.*)

Comparative costs of Ag plating and Cu/Ni/Cr plating; saleability, utility, design and manufacture of Ag-plated articles. Since there are large stocks of Ag in America this is suggested as a way out of the heavy demand on Ni and Cr.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Determining Surface Areas of Stampings, by N. Hall. (*Met. Finishing, December, 1941, Vol. 39, No. 12, p. 662.*)

Gives charts from which surface area of sheet brass, Cu, or steel may be determined from a knowledge of weight and thickness, with an accuracy sufficient for electro-plating purposes.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

The Technique of Quality Control. (*The Engineer, January 30, 1942, Vol. CLXXIII, No. 4490, p. 100; 2 figs.*)

A powerful inspection technique is to be regarded as the classic example in the application of modern statistical methods to the industrial field. The problem consists in obtaining a positive control over the quality of manufactured products, whether these be raw or semi-finished materials, processed piece parts, or completed assemblies. Charts for quality control by foreman (points) and by shop inspector (limits). A—General instructions: (1) application, (2) sampling schemes. B—Duties of the foreman: (3) sampling, (4) recording observations, (5) computing data, (6) plotting data, (7) foreman's interpretation of the chart. C—Duties of the shop inspector: (10) computing and plotting control limits, (11) judging and interpreting of charts, (12) number of groups on which limits should be based, (13) predicting limits, (14) meeting drawings and specifications.

Chromium Recovery. (*Automobile Engineer, January, 1942, Vol. XXXII, No. 419, p. 35; 4 figs.*)

The large and ever-increasing scale upon which chromium plating is employed has led to some remarkable loss figures. Chromium is a metal of high cost and comparative scarcity, yet in one plant investigation showed that nearly one hundredweight of the metal was lost each working day. Various processes for conservation and recovery are set out in detail, and the processes are compared in tabular form.

WELDING, FLAME-CUTTING, BRAZING, SOLDERING.

Arc Welding of Cast Iron. (*Welding, February, 1942, Vol. X, No. 1, p. 12; 9 figs.*)

Pre-heating: (1) critical zone, (2) safe zone, (3) small holes drilled, tapped, and plugged at extreme ends of the crack to prevent it extending. Repair of fractures. Preparation by grooving. Use of reinforcing bars to repair fracture. Strength of the joint. Welded joint in fracture in a machined surface: (1) machined surface, (2) depth of recess made to accommodate weld deposit, (3) crack, (4) final junction "soft steel."

The Repair of War-damaged Machine Tools by Welding. (*Machinery, February 26, 1942, Vol. 60, No. 1533, p. 121; 11 figs.*)

Welding plays an important part in the repair of war-damaged machine tools. Much of the work necessary is of such a nature as to demand the services of welding specialists. Usually the worst examples of damaged machine tools are those taken from factories where large fires have occurred. The action of high explosives results also in serious breakages. Bed of a grinding machine after repair by welding. Typical example of a fractured casting. Repaired casting in the assembly bay after alignment tests. Drawing showing a repair carried out on a fractured lathe bed casting, &c.

Methods of Testing Spot Welds, by R. E. Bowman. (*Welding, February, 1942, Vol. X, No. 1, p. 305; 6 figs.*)

Inspection of spot welds. Charts showing the dispersion in the strength of single spot lap welds made with different types of equipment. Weldability tests. Tests for ductility of the spot welds. Tests for corrosion resistance. Microscopic examination of spot welds. Fatigue tests and service tests.

Built-up Surfaces and Apparatus, by J. G. Magrath. (*The Machinist, February 14, 1942, Vol. 85, No. 47, p. 1087; 14 figs.*)

Built-up surfaces may be flame hardened, too. To make best use of all phases of this process, a familiarity with available apparatus is most essential. Ordinary welding or heating torch outfits may be employed for simple flame hardening. Separate quench apparatus is used. A standard two-flame tip bent pincher is shaped to heat small gear teeth along their faces. The quench tube plays the quench stream over the tooth, behind the flames. Water-cooled torch outfit. A diagram of an integral heating and quenching tip shows the relation of flame and quench jets to each other, and to work being flame hardened. Adjustment of tip spacing to suit work. A gear-hardening yoke assembly with a water-cooled torch. A flexible indexing mechanism of spreader yoke and arms is used for flame hardening the faces of bevel gear teeth.

Flame-cutting, by I. Stewart. (*The Machinist, February 7, 1942, Vol. 85, No. 46, p. 340E; 2 figs.*)

Chemistry involved. Effect on steels. Low-carbon steels. Medium-carbon and alloy steels. Mechanical effects of flame-cutting. Principles of flame-cutting.

Substitute Solders, by F. N. Rhines and W. A. Anderson. (*Metals and Alloys, November, 1941, p. 704.*)

A table has been made of 75 alloys which have been proposed as soft solders and as substitutes for the standard Sn-Pb compositions. The alloys have been subjected to a series of standard tests of comparison. All the tests were made with references to Cu as the metal being joined. Alloys containing reduced amounts of Sn, rather than Sn-free solders, were most acceptable for soldering Cu. The Sn-Pb-Cd combinations appeared most promising. Of the tinless type the Pb-Cd and Pb-Ag series were most attractive.

(Supplied by the British Non-Ferrous Metals Research Association.)

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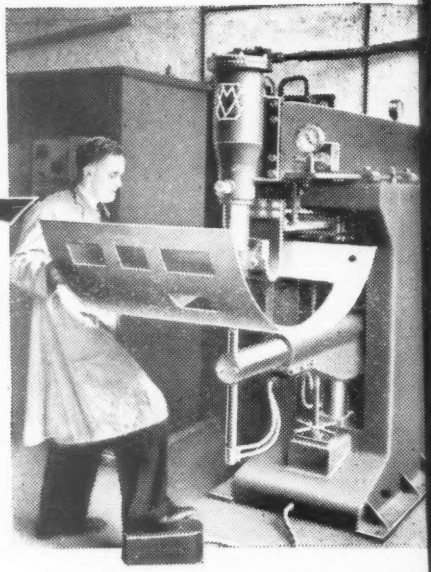
Electric Spot Welders



The photograph shows a "Metrovick" 390 kVA Spot Welding Machine in operation.

Electric spot welding machines possessing excellent features of design including—

1

Pressure is applied by a direct acting air cylinder which provides maximum speed of follow up of the electrodes during the formation of the weld.

2

Control is fully automatic, allowing continuous spot operation if desired.

3

Ignitron programme control provides reduced heat treatment current after completion of weld, and instantaneous pressure increase at any desired stage of weld cycle.

4

Design allows stiffeners to be welded on to large curved panels without reversing. The photograph clearly shows this.

Metrovick Welding Machines

A complete range of all types of welding sets is available, as well as "Metrovick" Electrodes for all purposes.

SEND FOR LITERATURE ON THIS SUBJECT

METROPOLITAN Vickers ELECTRICAL CO., LTD
TRAFFORD PARK ··· MANCHESTER 17

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All communications regarding advertisements should be addressed to the Advertising Manager, T. G. Scott & Son, Ltd., Three Gables, London Road, Merstham, Surrey. Phone, Merstham 316.
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